THE GREAT LAKES AND MICHIGAN

SPONSORED BY THE
GREAT LAKES RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN

AUSPICES OF THE SUMMER SESSION

UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

JUNE 23 - 24, 1955

FOREWORD

"The Great Lakes and Michigan", a program organized and sponsored by the Great Lakes Research Institute[1] was under the auspices of the University Summer Session and was the first of a summer-long series which had as its central theme, "Michigan".

President Harlan Hatcher's opening lecture the afternoon of June 23, entitled, "Michigan and the Great Lakes" was followed that evening by an address, included here, by General A. G. L. McNaughton, Chairman, Canadian Section, International Joint Commission, on "The Significance of the Seaway to the Provinces and States of the St. Lawrence-Great Lakes Basin."

The following day was devoted to two panel discussions. The morning session, ably presided over by Milton P. Adams, Executive Secretary, Michigan Water Resources Commission, was concerned with the general area of "Water Quality and Water Usage of the Great Lakes" and had the following participants and topics:

1. Water Conservation
   Stanley G. Fontanna, Dean, School of Natural Resources, University of Michigan
2. Water Quality and Water Usage of the Great Lakes Public Water Supplies
   L. G. Lenhardt, General Manager, Detroit Water Board
3. Industrial Usage, Including Thermally-Developed Power
   Vincent S. Madison, Director of Areas Development, Detroit Edison Co.
4. Great Lakes Navigation
   Harley F. Lawhead, U.S. Corps of Engineers
   Vice Col. A.C. Nauman, District Engineer, U.S. Corps of Engineers
5. The Great Lakes Basin Compact
   Nicholas V. Olds, Assistant Attorney General, State of Michigan

The afternoon session, concerned with the "Present Status of Basic Scientific Work on the Great Lakes" had Professor J. T. Wilson as its discussion leader and the following participants and topics:

1. Levels of the Great Lakes
   Lt. Col. Edward J. Gallagher, District Engineer, U.S. Lake Survey, Corps of Engineers
2. Beach Erosion
   Dale W. Granger, Hydrology Division, Michigan Water Resources Commission.
3. Geology
   James T. Wilson, Professor of Geology, University of Michigan, and Chairman of the Council, G. L. R. I.
4. Currents and Water Masses
   John C. Ayers, Associate Professor of Conservation, Cornell University, and G. L. R. I.
5. Fisheries
   James W. Moffett, Chief, Great Lakes Fishery Investigation, U.S. Fish and Wildlife Service, and G. L. R. I.

Dr. J. Murray Speirs, Secretary, Great Lakes Research Committee of Canada very kindly agreed to act as Recorder for the panel sessions. It is due to him that we are able to present here transcriptions of certain papers and discussions which were recorded through the kind efforts of Professor Karl F. Lagler, School of Natural Resources, University of Michigan. It is a pleasure to express our thanks to Drs. Speirs and Lagler at this time.

Finally, we wish to express our appreciation to President Hatcher, General McNaughton, Milton P. Adams, and panel members for their splendid contributions to this most successful program, and to the Director of the Summer Session, Harold M. Dorr and Charles W. Joiner, Chairman, Special Summer Program, for their generous support.

F. K. Sparrow
Program Organizer and Secretary,
G. L. R. I.

[1] An account of the first program sponsored by the Institute, namely, "A Conference on the Upper Great Lakes" was issued in 1953.

TABLE OF CONTENTS

THE SIGNIFICANCE OF THE SEAWAY TO THE PROVINCES AND STATES OF THE ST. LAWRENCE-GREAT LAKES BASIN

by
General A. G. L. McNaughton,
Chairman, Canadian Section,
International Joint Commission

I appreciate very much indeed the opportunity which has been given to me to speak this evening to this distinguished audience which has been gathered together by the University of Michigan to study and discuss, and to interchange views, as to the effects which it may be foreseen will follow logically from the removal of the last of the barriers which at present still stand across the route of transportation by ocean vessels from the North Atlantic to the Great Lakes. I refer in particular to the situation on the short section of the St. Lawrence River between the Port of Montreal and Lake Ontario—but this, of course, is only a part of the connected seaway project which has other essential components elsewhere.

Above this section of the St. Lawrence, with its existing limited navigation capabilities, in the Great Lakes and their connecting channels, both in Canada and in the United States, we have large fleets of vessels of specialized types. These down the years have been developed to meet the environmental conditions which exist and to serve the trade and commerce of the region to the best advantage by the seasonal movement of the immense tonnages demanded for the bulk cargoes of coal and oil—of ore and steel—of grain—of pulp and paper and of other raw materials needed for the complex and varied industries which have come to be established. And the smaller vessels of these fleets serve also to carry the products of the industry of the Great Lakes area for the export trade eastward through the St. Lawrence River from Lake Ontario for trans-shipment at the Port of Montreal. Some portion of this export trade also may move southward from Lake Michigan, after trans-shipment at Chicago, by way of the Illinois Waterway.

By the same act which will confer on the Lake fleets the freedom and opportunity to move down into the St. Lawrence, the way is opened for the seagoing merchant ships of other nations to enter the Great Lakes from the oceans and there will then remain no physical bar to these movements in due season, other than the need to be able to navigate in a 27-foot depth of fresh water.

These ships from overseas may bring cargoes which originate in any country of the world, and they will deliver their burdens direct to Great Lakes ports and then return to the oceans carrying merchandise loaded here which no longer will be subject to bulk-breaking and trans-shipment at some intermediate place en route to rail or craft of lesser draft for movement to an ocean port where another trans-shipment is now required.

It is true that in anticipation of the "great change" some scores of smaller foreign ocean-going ships now ascend the St. Lawrence each year on 14-foot draft, but the volume of this movement is as yet so small that it scarcely attracts attention. It is, however, a foretaste of what is to come. It is a venture organized, as a preliminary, by enterprising firms from overseas in an endeavour to gain advance experience which will prove, no doubt, most profitable a few years hence when, with the deeper drafts and heavier loadings, the opportunities will come for the entry of new fleets of specially designed ocean-going vessels into the carrying trade of the St. Lawrence-Great Lakes Basin which heretofore has been largely a monopoly of local interests.

This monopoly will exist no more when, as is forecast, in the year 1959—that is, four years hence—the great projects for navigation which are now in hand will have been completed by Canada in the Canadian Section of the St. Lawrence from the Port of Montreal to Cornwall and thence upstream, by joint endeavour of the United States and Canada, in the International Section of the river into Lake Ontario. Here, in this international reach, advantage is being taken of developments for power to assist in the provision of facilities for navigation and so to lessen the expense of what otherwise might have been a considerable financial burden on shipping.

That the opening of the Great Lakes to ships that sail the oceans of the world will bring great change not only in transportation but also in industry and trade and commerce no one, I think, can doubt; and far-reaching consequences will follow, even, perhaps, on modes of life and culture! Evidently we stand at the portal of a new experience of a dynamic order which will be characterized for the individual citizens of the United States and Canada in the Great Lakes regions by more direct, more forceful and more intimate competition with the peoples from overseas whose ships and goods will come to dispute our markets here and elsewhere.

To anyone who knows the men and women of these parts, whether of the United States or of Canada, this is not a new condition to be regarded with fear or to be faced with timidity or indeed to be taken as a reason for complaint. On the contrary, it presents a remarkable opportunity which I am sure we all should welcome for the stimulation it will give in our endeavours at home, and because it well may take us out from this richly endowed and strongly held base into new and ever-widening activities in useful and remunerative service abroad, and this surely is something to be sought by those who are virile and able and confident.

And in justification of this deep confidence in the

Seaway and in the great benefits which it will confer, I hope that in the course of your studies you will have an opportunity to analyse the forecast of movements in the various commodities which make up the potential traffic of the St. Lawrence. These have been estimated by the Canadian Department of Trade and Commerce in December 1950 in a total of inward and outward bound cargoes of some 44. 5 million tons per season.

You will, I think, find it instructive to compare the Canadian figures in detail with the somewhat larger forecast of 57-84 million tons given earlier in 1950 by the U. S. Department of Commerce, (Secretary of Commerce Sawyer, Hearings of Committee on Public Works, February and March, 1951). Now also you will be able to consider the Canadian figures as they have been scaled down to represent expectations in the years immediately following the opening of the St. Lawrence Seaway to a total of 31 million tons per season, which is the figure recently put forward by the officers of the Canadian Seaway Authority. These officials by reason of their position have of course to take a very realistic, and even a pessimistic view of traffic possibilities because under the present organizational arrangement they carry the responsibility for proposing the rates of tolls which will be needed to provide the revenues required to meet the costs of operation and maintenance of the new works for navigation.

I am sure you will find these forecasts very enlightening in throwing a useful light on developing business opportunities in many fields, but since they are esentially not proved facts but the varying views of experts, I believe that they can best be discussed with you by specialists in the field of transportation and business economics, to whom I propose to leave these statistical predictions so that I can have a little more time for other aspects of the great national and international projects on which we are engaged, and which I believe are matters which will merit your consideration at this time.

However, at this point, to sum up the beneficial economic consequences which we foresee will come from the new facilities for navigation, I would like to refer the members of this audience to a statement made recently by the Hon. Lionel Chevrier, former Canadian Minister of Transport, and now President of our St. Lawrence Seaway Authority, as his conclusion following a detailed survey of the probable effects of the navigational improvements. Mr. Chevrier forecasts, for example, an inward annual movement and use of Labrador iron ore in the Great Lakes area of ten million tons. This is first quality ore for blending. Most of it, I think, will go to U. S. blast furnaces south of Lake Erie, though it is probable our furnaces in the Hamilton area on Lake Ontario will also benefit to some extent.

Then there is the inward movement of foreign merchandise estimated at 15 million tons; of this, we in Canada hope British goods will constitute a considerable share so that more exchange will be available to the United Kingdom to expend on the purchase of our commodities, particularly wheat, which is a principal item of our export trade on which we expect the Seaway will reduce transportation and transfer costs by about five cents a bushel. Then too we expect large savings in costs for transporting pulp and paper, flour, coal, machinery, automobiles and other mechanical vehicles and equipment and the like.

These savings promise to be all the greater because the vessels entering the St. Lawrence with upbound cargoes of ore and other materials, in which there is little trade at present, will find it of advantage to carry on the return trip grain and other downbound cargoes, making for a greater economy in the use of shipping. This advantage applies particularly in the case of wheat export. Since our annual crops do not reach lakehead until late in the autumn, there is always a rush to move as much as possible before freeze-up. We hope, by the use of the additional shipping available for outward movement, to draw considerable benefit and to relieve the railways of a heavy seasonal load of uncertain economic advantage. In sum, it is estimated that the savings, direct and indirect, due to balancing up the inward and outward movements will amount to about $30 million a year.

In total, Mr. Chevrier estimates the benefits of the Seaway to the over-all Canadian economy at some $100 million annually, which is several times the total of the annual charges for maintenance and operation of the new navigation facilities, including interest on investment—a consideration which leaves a substantial surplus available for application in benefits to all who are concerned—to those who produce our goods for market—to those who transport them—and also to the very important people whose good-will we especially seek—those who purchase our products.

Like many other questions of national economics, it is not possible to develop specific figures with complete confidence. All we can hope for usefully is to express an order of magnitude for the benefits to be brought about by the improvements to navigation in question. The ramifications are far too complicated for more precision than that. We must in the circumstances place our dependence on the views as to the general effects which those best informed have come to believe will result, and in this case Mr. Chevrier is speaking for a nation which has long been united on the subject, there being no important section of opinion which does not have faith in the highly beneficial results which will come about.

I have not seen any recent official estimate of the economic benefits of the Seaway to United States trade and commerce, but by reason of your present much larger population and industrial development in the tributary area, I would expect this to be much greater than the large returns I have indicated for Canada.

All in all, this great endeavour on which we now are well embarked is an affair of vast significance to every one of us, and so I think its early beginning and especially the troubles and difficulties which we have experienced, should merit consideration, more particularly in relation to the means and methods through which, with long-continued patience down the years, these obstacles to progress have at last been overcome.

Perhaps by knowing something of this past history we may be able to avoid in the future any repetition of the difficulties which we have experienced, and which have, perhaps unnecessarily, cost us the use of the St. Lawrence for deep water navigation and power for upwards of two decades.

From the Atlantic through the Gulf of St. Lawrence and up that river to a point near the City of Quebec, the greatest ships which in their time have sailed the oceans of the world have always, in peace, had open passage for commerce during the season of navigation. Above Quebec the channels were restricted originally to a depth of some 10-1/2 feet, but from the earliest days of the regime of France the successive authorities which governed Lower and Upper Canada and more particularly the Federal Government of Canada, since it was established at Confederation in 1867, have made it their business to dredge out the shallow sections and to extend and improve the facilities of navigation for ocean shipping.

Today, the St. Lawrence ship channel provides safe passage to the harbour of Montreal, a thousand miles up-river from the sea, with a minimum controlling depth in navigation channels of 35 feet. Every care is being exercised to ensure that developments continue as may be shown to be desirable by progress in the art and science of inland navigation. In matters of channel width, alignment, freedom from obstruction, lighting, radio aids, harbours, wharfage, storage, loading, repair establishments and the like, I can say with every confidence on the evidence of many masters of vessels which ply this magnificent thoroughfare of commerce, that there is no other waterway in the world which is better provided.

And we in Canada are happy that in the Treaty of Washington of 1871 we were able to continue and extend, by Article XXVI, the courtesy which had previously been accorded by the Webster-Ashburton Treaty of 1842 in respect of Long Sault and Barnhart channel that the navigation of the St. Lawrence below the boundary at the 45th parallel of north latitude "from, to, and into the sea, shall forever remain free and open for the purpose of commerce to the citizens of the United States, subject" of course "to any laws and regulations .... of the Dominion of Canada, not inconsistent with such privilege of free navigation".

So long as no tolls are levied on our own shipping, "free" in this case means without tolls also, as well as in the sense of freedom to come and go at will. So, except for the customary charges to individual ships for pilotage, wharfage and the like, we have been glad to give to the citizens of the United States, as well as to those of other nations, the use of the great facility of the St. Lawrence ship channel for inter-nation trade. I am happy to say that I know of no case of any serious complaint from either side in all the long years since these privileges were first accorded.

When an arrangement has a long record of satisfaction, it is, I think you will agree, the part of wisdom that it should continue; and so in relation to the plans for the construction and operation of the International Section, Canada will continue in all respects her existing responsibilities in the National Section of the St. Lawrence from the Port of Montreal to the sea. It had been suggested at one time that there might be some prior joint arrangements with the United States on tolls or other charges—on priorities of shipping—on restrictions on the shipping of other nations or on their nationals which might make use of the St. Lawrence, but Canada has seen no need to make any change in her own complete jurisdiction in these or other aspects of the matter.

Our seaway authorities have indicated their willingness to listen to any representations which the United States as well as other nations may wish to make and to give sympathetic consideration to their requests; but power of decision of any point will remain where it always has been—with the Government of Canada—and will I am sure be exercised with responsibility and consideration for the rights of all.

Since, as I have said, there has been no trouble to date I cannot imagine that there should be any occasion for real concern in the future.

The privileges of the free and open navigation of the St. Lawrence accorded to the United States for the purpose of commerce on a basis of equality with Canadians are comprehended also in Article I of the Boundary Waters Treaty of 1909 which makes these rights mutual and extends them "to all canals connecting boundary waters and now existing on which may hereafter be constructed on either side of the line"; for Canada, these rights are specifically recognized as extending "to the waters of Lake Michigan".

In my description of the St. Lawrence Waterway as it stands at present, I pass next to its upper end at Lake Superior, where through Fort Williams, Port Arthur, Duluth and other great ports there passes a vast tonnage of commodities. The iron ore of Minnesota, despite the near exhaustion of the higher grades under the tremendous demand of two world wars, continues and expands with its taconites in concentrated form. and, increasingly, ore of premium quality flows in from the iron ranges in Canada to the west and north—the wood products of the adjacent regions and the grain from the Prairies add their quota in amounts measured in the millions of tons. The traffic which each year passes in and out of Lake Superior through the five locks of the St. Mary's River, four in the United States side and one on the Canadian, which have been built. side by side and in parallel, to accommodate it, represents an amount which now approximates to the total combined annual traffic of the Panama and the Suez.

Canada has the proud historic satisfaction of having built the first canal between Lake Huron and Lake Superior in 1797, but unfortunately this was destroyed in a raid in the subsequent war between our countries.

The immense traffic at the Soo, as all here will know, is now mostly carried from Lake Superior to Lake Michigan and Lake Huron and from thence to Lake Erie through Lake St. Clair and the Detroit River, in vessels of the type peculiar to the Great Lakes which have a fully loaded draft of about 22 feet. These special types of vessels have proved most efficient for lake transport and in cost per ton mile of bulk freight in inland waters they are far more economical than any ocean-going craft.

It has long been evident that with the opening of the Great Lakes to the sea an ultimate increase in usable channel depth to 27 feet would be needed, and already channels of 25 feet for down-bound and of 21 feet or better for the lightly loaded up-bound traffic have been made available in the connecting channels of the Upper Lakes by consistent action, principally by the United States, over a long period during which upwards of 55 million dollars have been spent on this project.

This amount includes the cost of construction of the MacArthur lock on the United States side at Sault Ste. Marie which is capable of taking the largest ships passing our present Welland canal between Lake Erie and Lake Ontario.

The present Welland ship canal is the fourth of a series built by Canada, the first of which, with a four-foot draft, was completed by a private company in 1829. The second, built by the Government of Upper Canada, with a nine-foot draft, was opened in 1845. The third, on a much improved alignment, increased the depth to 14 feet in 1887.

The construction of the ship canal, begun in 1913 to provide for the tremendous growth in the movement of iron ore from Minnesota and of grain which followed the extraordinary rapid settlement of our Prairie Provinces, was suspended in 1916 because of shortages in materials and manpower brought about by Canada's heavy participation in World War I, which was then in the extremely critical stage of the battles on the Somme.

After our troops returned from Europe, construction was resumed, but progress at first was very slow.

In 1921 the Report of the International Joint Commission concerning the improvement of the St. Lawrence River between Montreal and Lake Ontario for navigation and power (67 Cong., 2nd Ses., Sen. Doc. 114) recognized the Welland Ship Canal as an essential link in the St. Lawrence-Great Lakes deep waterway, and recommended that costs "be apportioned between the two countries on the basis of the benefits to be derived by each country from the use of the waterway" (Answer (a), Question 4).

With this encouragement and the prospect of sharing, at least to some degree, the heavy costs, about 1928 when some of the financial burdens of World War I had been liquidated, work was again pressed and the canal was opened to traffic on August 6th, 1932, in the presence of members of the Ottawa Imperial Economic Conference of that year. This event took place shortly after the signing of the St. Lawrence Deep Waterway Treaty between Canada and the United States which occurred on July 18th, 1932, and which seemed then to give definite confirmation to the hopes for United States co-operation in making early progress with the Seaway, which had been encouraged by the satisfactory progress of the treaty negotiations.

This was most important to Canada because the Welland Ship Canal standing alone represented a very heavy burden on Canada for interest, operation and maintenance charges which it could not be expected, in a toll-free enterprise as was then the established custom, would be balanced by benefits commensurate with the general economy of the nation. Unfortunately, in the long years of disappointment which followed this proved to be all too true. Even as late as 1953, for example, the total traffic on the Welland was only 19,572,000 tons, which is considerably less than half the capacity available. Of this, 16,973,000 was down-bound and only 2,599,000 up-bound—a very unbalanced load. Of the total, 11,958,000 or 60%, originated in or was destined to ports in the United States. In other words, as matters have worked out the very heavy burdens assumed by Canada for the Welland have had their effects somewhat largely in benefits to the trade and commerce of the United States.

The Welland Ship Canal overcomes the fall of 326 feet across the Niagara escarpment which separates Lake Erie from Lake Ontario. The locks have a length of 800 feet, a width of 80 feet and a depth on the sills of 30 feet. The canal itself has been dug to 25 feet which is sufficient to accommodate existing shipping; it may readily be dredged to 27 feet or to 30 feet whenever additional depth may be required.

There are seven locks in series, each with a lift of from 43.7 to 47.9 feet, and a guard lock near Lake Erie which is 1380 feet long between the inner gates. This is said to be the longest lock in the world. Locks 4, 5 and 6 at Thorold are in flight (that is, in sequence, with no intervening section of canal), and have been twinned (that is, each lock is side by side with a duplicate). Locks 1, 2 and 3 at present are single, and they are also in flight. In consequence, they present the limiting factor on the over-all traffic capacity of the canal; this can be greatly increased by the simple expedient of twinning Lock 2. The other single lock also can readily be twinned when this will be required by the growth of traffic. Meanwhile, the Welland presents no limiting factor on the prospective movement of shipping between Lake Erie and the sea by way of the facilities now under construction in the St. Lawrence River. The locks in these sections are being built to dimensions which have been standardized with those on the Welland and so they are of similar traffic capacity for like conditions.

In the St. Lawrence the season of navigation is on the average only 230 days, in place of 260 at the Welland. The extra period when the Welland is open is of importance because of the considerable traffic at this point which is local to the Great Lakes and which can continue to move with advantage in the season after the St. Lawrence is closed for the winter.

The Welland Ship Canal as of August 6th, 1932, the date of opening, had cost Canada a total of $131,900,000, on capital account. Much of this cost was incurred at a time of grave financial difficulties during World War I and in the post-war period of even greater financial stress which followed, when Canada had to pay upwards of five per cent for funds for construction. As a result, the real out-of-pocket expenditure is of the order of two to three times greater, for which to date we have had little in the way of return through the use of these costly facilities in the trade and commerce of Canada. It has been estimated that the replacement cost of existing facilities at the Welland would exceed $350 million at current prices.

In view of the very heavy investment by Canada in the Welland, which could only be used to full advantage as a component of an over-all deep waterway from the sea to Lake Superior, you will appreciate the interest with which the United States proceedings in reference to the ratification of the Treaty of 1932 were followed in Canada. The high expectations in which we had entered this arrangement began to fade almost from the start. The Treaty came at last to a vote in the United States Senate on March 14th, 1934, with the result, yeas 46, nays 42, not voting 8; a two-thirds affirmative vote of the United States Senate thus being lacking, the treaty failed of ratification. As a consequence of this failure of the United States to ratify the treaty, the Canadian Prime Minister did not submit the treaty to the Parliament of Canada. No useful purpose would have been served in so doing and, after the

event, it might only have aggravated the already strong feelings on the subject.

However, this set-back did not seem to have unduly discouraged Mr. Cordell Hull, the U. S. Secretary of State, under whose direction, with the strong support of President Roosevelt, studies continued in various committees and by the U. S. Army Engineers, resulting in new specific proposals to Canada in 1938. These proposals it seemed were primarily designed to expedite the construction of the power plants in the international section of the St. Lawrence and involved the plan of a "single stage" at Barnhart, which, although it was viewed with considerable anxiety by downstream interests in Canada, would be more effective from the point of view of power.

By this time, however, Quebec and Ontario had made substantial progress with power developments elsewhere and there was reluctance to proceed with the power projects on the St. Lawrence until there was assurance that our markets would be able to absorb these, for the time, very large increments.

However, this situation of a surplus of power in Canada changed with the outbreak of war in Europe in 1939, in which Canada was involved from the beginning, and by 1941 under the impulse of war needs, and following the favourable advice of joint Canadian and United States engineering groups in which the advantage was emphasized of the waterway in the war effort of the two countries, an "Executive Agreement" was formulated under date of March 19th, 1941, which was most promptly transmitted by the President to Congress two days later for ratification.

This Agreement sought to distribute the cost burden by arranging that the works in the International Section would mostly be in the United States and be built by the United States, thus balancing to some extent the heavy effort and expense to Canada required in the section from Montreal to St. Regis.

An "Executive Agreement", the United States authorities explained, would be subject to a simple majority of the Congress and not to a two-thirds majority of the Senate, a requirement which had prevented the ratification of the 1932 Treaty. However, in the result, the document remained year after year undealt with in Congress until finally, in 1952, eleven years after signature by the competent authorities of the two countries, we ourselves turned to another course and withdrew from the Agreement of 1941 which had been made with the Government of the United States and which, like its predecessor, the Treaty of 1932, had failed to obtain the affirmative vote of Congress required despite the consistent and determined support for the deep waterway which had been evidenced by each President in turn from President Harding through Presidents Coolidge, Hoover, Roosevelt, to President Truman, who was then your Chief Executive. You will, I am sure, appreciate the grave concern which these matters have caused us, and it is well, I think, that this concern and frustration should not be entirely forgotten on both sides.

Turning now to the physical situation which had come to exist in the St. Lawrence by the time of the 1941 Agreement, and to the developments in plans which have subsequently taken place:

With the completion of the Welland Ship Canal, there had come into existence on the Great Lakes system from Lake Superior to Lake Ontario inclusive, facilities for navigation on a basis of 27 feet depth. All locks required had already been built with 30 feet or more on the sills and so, it becomes only a matter of simple dredging to increase the depth of the connecting channels as this should come to be desirable in the future.

From the sea upwards to Montreal, as I have already mentioned, there was in existence a channel of 35 feet depth or more, and this channel presented no limitation whatsoever to any ocean ships which we might reasonably expect would wish to use it. Moreover, the same steady persistence by Canada in the pursuit of the fulfillment of the over-all plan of opening the Great Lakes to the sea is evident in this section of the river and on up to Beauharnois, where, for example, in connection with the development of power the channels for the usable depth of 30 feet eventually to be provided when needed for navigation have already been substantially completed to more than 27 feet, the present requirement; all that remains to be done at Beauharnois to carry navigation past the rapids at that point is to build the locks, designed with 30 feet on the sills like all the others of the system, and finish the excavation of the approaches which have been laid out to fit right in with the existing channels and structures.

At Lachine, the earlier plans for a joint development for power and deep water navigation have had to give way to plans for navigation only, which will involve a canal some ten miles in length in the Laprairie Basin with two locks at Côte Ste.Catherine and one at Victoria Bridge. This bridge, together with the Jacques Cartier and Honore Mercier Bridges, will have to be reconstructed or raised so as not to impede the heavy flow of vehicle traffic from Montreal to the South Shore.

This change in plans poses some very difficult problems, particularly in regard to the effective regulation of flows through Lake St. Louis and past the port of Montreal which it seems will be the limiting factor on what can be done to relieve the situation of the high levels on Lake Ontario which are causing anxiety to property owners along the shores in both countries. The changes in plans for the development of the Lachine Section are a direct consequence of the long delays which the St. Lawrence project has experienced, because with little expectation of progress, the Government of Quebec had necessarily to turn to other sources than Lachine for power for Montreal, and in consequence the gigantic project for more than two million kilowatts on the Bersimis River in Quebec has been placed under construction. This increment of power capacity has been estimated as sufficient to meet requirements for load growth in Quebec for some years to come, and so under the arrangements now made, the development of Lachine for power will stand over for the present. The Chairman of the Canadian Seaway Authority has stated that this will not materially affect the navigation project as a separate undertaking, but it seems it may impose restrictions for the time being on the higher flows which would otherwise be permissible on occasion, and of course very advantageous to power and to lakeshore interests upstream.

I now turn to the short section of the St. Lawrence from St. Regis opposite Cornwall, where the middle of the river is the international boundary, to Prescott to which deep water extends some 67 miles

down river from Lake Ontario. This is the international part of the project between Montreal and Lake Ontario which is one of the subjects of the recommendation for construction made by the International Joint Commission to the Governments of Canada and the United States in 1921, and since repeated many times by other competent bodies.

Between Montreal and Prescott, which is opposite Ogdensburg, the presently existing facility for navigation is the system of 14-feet canals built by Canada many years ago to overcome the difference of level between Montreal Harbour at 20 feet above sea level and Lake Ontario with a range of levels from 249.3 to 242.7, which is about 246 feet mean.

This 14-foot canal system has a total of 21 locks with ruling dimensions of 240 feet length and 45 feet width as compared with the ruling dimension of 30 feet depth on the sills, 800 feet length and 80 feet width which, as I have mentioned, now exist from Lake Ontario to Lake Superior inclusive, and the somewhat greater ruling depth which is now available from Montreal to the sea.

This short section of the St. Lawrence River is now only passable by small ships of the 2000 ton class and thus presents a barrier to the trade and commerce of the basin which either prevents its development or at least requires the expensive and time-consuming process of trans-shipment once, often twice and sometimes more, thus creating a burden which has long been felt to be intolerable, more particularly as the effort needed to overcome it cannot be regarded with present day facilities for construction, as anything which is really of any very great magnitude.

The International Joint Commission Report of 1921, together with the technical report made by the subsequently appointed Joint Board of Engineers on November 16th, 1926, has set the general pattern for the physical plan of development in the International Section which has ever since been followed quite closely in principle.

In detail, while the number of locks, their dimensions and their general location on the river has been little altered in successive plans, they have been placed sometimes on one side and sometimes on the other, emphasizing that their position in either country was of minor significance from an engineering point of view.

As regards power, the first plans contemplated a division of head between two sites. These arrangements have given way to a single site which is placed in the approximate position of the original lower site in order to secure the maximum head possible, thus meeting the views repeatedly urged by the United States authorities.

Near Iroquois, a few miles upstream from the location of the upstream site for power at Cryslers Island originally proposed, the plans now call for a great regulating work with a large number of gates opening sub-surface. These have the function of controlling the level of Lake Ontario and regulating the outflow. No turbines or generators will be installed.

These works at Iroquois and the associated dykes together with the power plant at Barnhart and its associated dams and dykes, constitute the double line of protection which has been consistently desired by the Canadian authorities as a necessary assurance of protection in holding back the waters of Lake Ontario from flooding the lower river, the large power plant at Beauharnois, the immensely rich region around Montreal and upstream and downstream therefrom.

The area on the shores of Lake St. Louis and below to Lake St. Peter, inclusive, is very sensitive, indeed to conditions of level and flow in the St. Lawrence, particularly in the season when the Ottawa is in flood. Here, very great damage might be done by even a seemingly slight departure from the conditions of the natural flows to which the shore property owners have become adjusted, and which would have continued to exist except for the new channels to be cut through the Galops Weir above Morrisburg, the river feature which has naturally controlled the levels and outflow from Lake Ontario for countless ages.

These new channels at the Galops are to be excavated primarily for the benefit of New York and Ontario power and the regulating works will be built, as one of the conditions of approval, at the expense of their authorities to replace the natural control by an artificial control. This control structure will be operated under the direction of the International Joint Commission to ensure that complete protection of downstream interests, which is their right, and also to give all the benefit possible to property owners upstream on the St. Lawrence and along the shores of Lake Ontario in both countries. After prolonged study, the Commission is satisfied that all interests upstream as well as down, and including power and navigation, will in fact be substantially benefited by the new regimen of levels and flows which will be set up.

Turning back again to my chronological account. All through the war years of 1941, 1942, 1943, and 1944 the people in Canada, where the support for the deep waterway had come to be practically unanimous without regard to political parties or regional, class or other interest, were encouraged by the support being given to the Executive Agreement of 1941 in the Congress, by the President, and by various other leaders of public opinion including the Governor of the State of New York, Mr. Dewey, and the Chairman of the Federal Power Commission, both of whom were strong advocates of early power development. if not of navigation. On the other hand, the Maritime Association of the Port of New York in April 1944 came out in opposition to the project, urging postponement of legislative action for ten years, and it appeared that this attitude had developed strong support from United States shipping and railway interests along the Atlantic seaboard.

From thence forward, I must say that we in Canada found it very difficult, indeed, to understand what was going on in the United States, for the argument in Congress shifted from the question of the real practical advantages of the navigation and power aspects of the project to the somewhat (to us) obscure question of the merits or demerits of various procedures including the abstruse question of the constitutionality of an Executive Agreement, such as that of 1941.

We were even more disturbed in 1945 and 1946 when the method of an Executive Agreement, which had appeared to be again accepted as a basis of procedure, began to be coupled with reservations on important clauses, mostly, it seemed, concerning navigation and related aspects other than power.

You will recall that the matter came up again in the new Congress of 1947 when, although World War II had ended, the emphasis came to be laid on defence considerations. The possibility of making the project self-liquidating through the levying of tolls also was discussed and clearly commanded wide support in the United States.

Through all these years, the project as set forth in the 1941 Agreement had had the full support of Canada, though I must say that I think this was quite extraordinary. However, forceful statements to this effect were made repeatedly by the Prime Minister and by many of his colleagues in the Government. They made it clear that whenever the United States would be willing to proceed, our country continued to stand ready to go on with the combined project for navigation and power as set out in the Executive Agreement of 1941 in which the burden of costs and responsibilities was sought to be equalized by a distribution of the works.

At first, in view of our traditional custom of toll-free waterways, we did not take kindly to proposals made to Congress which would introduce this feature and require a further executive agreement to fix the rates of toll and other charges in advance. We had come also not to like, either, the suggestion which was made to set up a joint commission to administer these matters throughout the whole length of the waterway.

However, by 1947 we in Canada had come to accept the principle of tolls and to realize that since the tolls to be charged for navigation and the revenue to be derived for power in the St. Lawrence project would evidently be amply sufficient to make each part self-liquidating, and indeed highly profitable, the question of the distribution of the financial burden for construction between the two countries had ceased to be important, and so it no longer mattered very much which country raised the funds for capital expenditures and carried out the works.

We were strengthened in these views by a realization that although the works for navigation and power in the St. Lawrence might cost about 900 million dollars, if one had a sense of proportion this was not really a very large amount for two leading wealthy industrial countries like Canada and the United States to expend over a period of five or six years. In fact, in total, the amount was less than half as much as the annual sales value of the output of one at least of the larger American electrical manufacturing corporations.

In 1947 Mr. St. Laurent, as Secretary of State for External Affairs, announced Canada's acceptance of the principle of tolls, but not by any manner of means of the United States proposals for their joint administration.

In 1948, and again in 1950, the Canada-United States Joint Board on Defence took under particular consideration the matter of the benefit of the waterway to continental defence and united in putting forward a Resolution to the two Governments recommending the 1941 Agreement as it had originally been drafted. The PJBD Resolution of 1950 was read into the records of Congress by the Secretary of State, Dean Acheson, on February 20th, 1951 (Hearings, Committee on Public Works, H. R. 82-2, pg. 32).

In the preamble to this Resolution the Board made reference to the deterioration of the international situation indicating a period of protracted crises—requiring a steady increase in our military strength—pointed out that the St. Lawrence Seaway and Power Project would yield large additional supplies of hydro-electric power already needed in the N. E. U. S. A. and Eastern Canada which would be vital to expansion of our military strength—provide navigation facilities relatively safe from enemy action where most required to move war materials at less cost in money and resources—permit greatly increased shipbuilding also in relatively well-protected areas. The Board referred to Labrador ore as an additional reason for early construction in the interest of defence. The Board, after searching analysis, stated the project would increase military potential out of all proportion to expenditure in manpower and critical materials, much of which would be required to be used in any event as additional power had to be provided.

Having in mind these considerations and reaffirming its previous Recommendations for the construction of the St. Lawrence Project for Navigation and Power, the Board recommended:

> "That the two Governments take immediate action to implement the 1941 St. Lawrence Agreement as a vital measure for their common defence".

Thus by this action in recommending the construction of the St. Lawrence project for navigation and power the PJBD, which had been set up by President Roosevelt and Prime Minister King at Ogdensburg in 1940, joined its support to that given earlier in 1921 by the International Joint Commission, established by the Boundary Waters Treaty of 1909.

There is, therefore, on the public record the advice of the two bodies, each created by Canada and the United States jointly, to consider matters of mutual interest in peace and for defence, respectively. Both have recommended that the St. Lawrence project should be built—promptly.

As I have mentioned, the PJBD Resolution of 1950 was, like the previous one, directed to the implementation of the 1941 Agreement. It did not concern itself with the method by which this desirable objective should be achieved for the members of the Board were at the time well aware of the proposals which were even then under consideration in Canada. These proposals constituted a new approach which it was hoped might resolve the difficulties which existed with regard to the combined project for navigation and power in the United States, where the opposition was directed more specifically against the navigation features.

By this time, there was most important support for power which both New York and Ontario authorities were convinced was entirely economic and badly needed to relieve existing shortages. It had become evident that this would prove to be a very profitable self-liquidating investment from the day the plant at Barnhart would be brought into operation.

Now that tolls were acceptable in principle, the Canadian navigation authorities were equally satisfied that the amount which could be levied on the traffic in sight would be fully sufficient to meet capital and operation charges, with a handsome margin over to benefit all concerned, producers, carriers and consumers

alike. These views on the large potential benefits were also shared to some extent in the United States, more particularly by the Department of Commerce, but generally the opposing shipping and railway interests appeared to be in command of the situation.

It seemed, therefore, that in place of a proposal which combined power with navigation and which could continue to be blocked completely by the forces in the United States opposed to navigation improvements, it would be wise to separate power from navigation and place it under the direct auspices of New York State and Ontario, which were willing to proceed independently. With this arranged, Canada could undertake to add the navigation, which is the part of the undertaking which we have always considered the most important. We would do this at our own instance and at our own expense for the capital investment.

The way to such arrangements lay open as a matter of ordinary business already provided for in the existing diplomatic arrangements with the United States of America, through the Boundary Waters Treaty of 1909 and the International Joint Commission, and in consequence no new treaties or executive agreements or the like were required.

Accordingly, in 1951 the Prime Minister of Canada, Mr. St. Laurent, proposed to the President of the United States, Mr. Truman, that if he would agree to an Application to the IJC under the Treaty of 1909 for authority that the power works should be built by a Canadian entity (The Hydro-Electric Power Commission of Ontario was named) and a United States entity (not named at the time), each on their own side of the boundary and at their own expense and ultimate profit, then Canada would undertake to build at the expense of Canada on capital account not only the navigation works required in the National Section from the Port of Montreal to Cornwall-St. Regis, including Lachine and Beauharnois, but also the navigation works in the International Section, namely the locks at Barnhart and Iroquois; all the channels from Montreal to Lake Ontario would be dredged to a usable depth of 27 feet. Canada would also deepen the Welland Canal to 27 feet.

All these works would be in Canada where there were certain advantages, particularly in regard to the elimination of the need for continuing 14-foot navigation otherwise required, that would substantially decrease costs as against the 1941 plans and at the same time result in some improvement to navigation facilities in general in the International Section of the river.

President Truman agreed that this offer should be implemented by Applications to the IJC in similar terms on behalf of the United States and Canadian power entities for authority to proceed with construction of the power works and that meanwhile, and pending approval by the IJC under the provisions of the Treaty of 1909, he would make another attempt to induce Congress to accept the 1941 Executive Agreement.

The Applications were submitted to the IJC under date of June 30th, 1952, and after a long series of public hearings duly held to give everyone concerned the convenient opportunity to be heard, which is required by the terms of the Treaty of 1909, the IJC Order issued on October 29th, 1952. It had been approved by a vote of three Canadian and two American Commissioners in favour and one American Commissioner against.

On the basis of this Order which approved the power works and settled the joint procedures of construction, operation and regulation of flow in the International Section, the Canadian Government at once notified the U. S. Government that Canada would also proceed immediately with the navigation works between Montreal and Lake Erie, and that since the 1941 Agreement was now outmoded the Canadian Government would not proceed to ask Parliament for its ratification.

There is no occasion to describe to this audience the further debate which took place in Congress leading to the passage of the Wiley-Dondero Bill of 1953 which sought to bring the construction of the navigation facilities in the International Section back into United States territory, and to impose a number of conditions which were to prove unacceptable to Canada. I do not do so because these difficulties have since been settled or are on a fair road to settlement to the mutual advantage of both countries, and by consent.

In the upshot, the locks and canals at Barnhart and the navigation channels below and above, will be in the United States initially, and these works have become the responsibility of the U. S. Army Engineers, on behalf of the St. Lawrence Seaway Corporation, a body specially created by Congress for the purpose. At Iroquois, the lock by-passing the great regulating works at that place will be in Canada and will be built by the St. Lawrence Seaway Authority of Canada. For the future, when traffic justifies, the United States are authorized to build a lock also at Iroquoia, and Canada one at Barnhart and to this end the great dyke which, with the powerhouse at Barnhart and the dam at Long Sault, will hold back the waters of the St. Lawrence to make the immense pool which will extend upstream to Iroquois, will contain the masonry structures needed so that there may be no difficulty with then existing navigation and power facilities when the time comes, and Canada shall so decide, to build the lock on the Canadian side at Barnhart which will complete for her people the through-way from the sea to Lake Superior in her own territory, which her people now so ardently desire.

The matter of the tolls to be charged and their division has been remitted to the Canadian Seaway Authority and the U. S. Seaway Corporation for study and report, and when agreement is reached each government will be in a position to legislate insofar as its own locks are concerned. There is no proposal to set up any international jurisdiction which would transcend national authority in the national territories of either country. This is a useful simplification of proposals contained in the earlier draft treaty and other proposals which would no doubt have been found exceedingly difficult to operate in practice.

Likewise, in the power projects, clarity and simplicity have been sought. The powerhouse at Barnhart, which is also the main dam at that point traversing the international boundary, is to be built under joint arrangements as a matter of practical necessity, but the costs of powerhouse machinery and equipment are to be borne by the respective countries, each for their own, so that they will be entirely free to choose their own designs and to manufacture the turbines, generators and transformers and the like each in their own countries.

Apart from this, all costs for the dams, dykes, regulating works, channels for power, works for rehabilitation or protection of foreshores and for compensation to individuals, municipalities and others required to move out because of flooding will be divided equally and paid by the power entities, The Hydro-Electric Power Commission of Ontario in Canada and the Power Authority of the State of New York in the U. S. A.

The review, coordination and approval of all designs for power works in the International Section are subject to the St. Lawrence River Joint Board of Engineers, recommended by the IJC and since established by the two Governments.

Control of levels and flows remains in the hands of the IJC and will be under the direction of the Commission's International St. Lawrence River Board of Control, which has already been set up and is now operating in an advisory capacity to the Joint Board of Engineers and the Commission, pending the completion of the regulating works at Iroquois which will enable it to take physical charge of these matters.

At the same time as it has been dealing with the organization of the power aspects of the project and with facilitating developments for navigation as it was enjoined to do by the Governments in the Applications, the Commission, as I have already mentioned, has been studying the levels of Lake Ontario in the interest of taking whatever action might prove to be practicable, without delaying the navigation and power projects, to reduce possible damage to the owners of shore property from flooding and erosion.

These studies, insofar as Lake Ontario is concerned, have now been completed, and an agreed recommendation has been made to the Governments which will substantially reduce the fluctuations of levels on the lake from a range of about 6.6 feet in nature to a range of four feet "as nearly as may be" under regulation. One of the most important features of these proposals is that the high levels are moved from the spring and fall months of high winds on Lake Ontario, which cause extensive erosion, to calmer periods where without wind action there is little damage.

As regards low levels, the selected range gives full attention to the requirements of navigation which under the principles of the Treaty of 1909 and the Applications of 1952 is an important consideration.

The power interests will be accorded the consideration to which they have a right, though perhaps not quite to the full extent they may wish as regards levels and flows which must be set in accord with requirements for the protection of life and property and the superior rights of navigation.

These proposals are now under review to test their effects in Lake St. Louis, at Lachine, and down river past the Port of Montreal. Here, while existing conditions may be varied, they must not, as I have said, be made worse than in a state of nature, however much the shore property owners and the power and navigation authorities upstream may wish to change natural conditions in their own interest.

And now to summarize the activities in progress at this time:

Downstream, the improvement of the St. Lawrence Ship Channel goes on normally and the Port of Montreal continues to develop at the instance and at the cost of Canada.

Upstream, the United States authorities, in accordance with traditional arrangements and to offset Canada's immense expenditures on the Welland, are giving consideration to the deepening of the connecting channels of the Upper Lakes to 27-foot clearance. At the Welland, the Canadian Government is about to do the same.

In the International Section the two power authorities are moving forward in complete agreement and association in the construction of the various power works and the enlargement of channels in accordance with the responsibilities they have undertaken. Among other matters on which notable progress has been achieved is at Barnhart, where the coffer dams for the joint powerhouse have been closed and the water is in course of being pumped out.

In the International Section also the respective seaway authorities are making substantial progress. In particular, I might mention that the contract for the Canadian lock at Iroquois has been let and excavation has commenced.

Thus, now, in a series of conveniently separated undertakings each under appropriate national administration, but each adequately coordinated in design and specification for mutually satisfactory performance, the St. Lawrence projects for navigation and power move forward to completion, when in the combined result they will effectively serve the peoples of both our countries, opening the St. Lawrence to our large lake fleets and freeing the channels of commerce for ocean ships to move our produce to, and our imports from, the markets of the world—providing large benefits in power to both nations—providing protection and relief against the damages of flood—benefiting everyone and harming none.

May I say that we in the IJC both in Canada and the United States count it a most remarkable privilege to have some part in bringing to fruition the St. Lawrence project for navigation and power originally envisioned by our predecessors on the Commission in 1921, that is, three and a half decades ago.

We are happy in this continuing evidence of the usefulness of the Commission and of the Boundary Waters Treaty of 1909, under which we operate, as a means for the reconciliation of conflicting views on matters related to the use of boundary waters and of initiating the building of great works required for the advantage of both countries.

These works for navigation and for power on the St. Lawrence, each in their several parts and under the management of their own proper authorities, now move forward in construction; and it seems in late 1958 or early 1959 or thereabouts we may with confidence expect the whole affair to reach completion for service thenceforward to both our countries in peaceful trade and commerce and also in war, should that eventuality come upon us.

INTRODUCTORY REMARKS

by
James T. Wilson
Associate Professor of Geology
Chairman of Council, Great Lakes Research Institute
University of Michigan
and
Milton P. Adams
Executive Secretary,
Michigan Water Resources Commission

The Great Lakes Research Institute of the University of Michigan is approximately ten years old. It was conceived in the last years of the war by a group of the faculty interested in the Great Lakes and was chartered by the Regents in 1945. Its primary purpose is to promote and encourage scientific investigations of the Lakes. The original Council of the Institute was made up of representatives from a number of fields. Over the years the council membership has reflected this broad interest. At various times faculty members from Anthropology, Astronomy, Biochemistry, Botany, Civil Engineering, Fisheries, Forestry, Geology, Geography, Geophysics, Marine Architecture, Meteorology, Public Health, and Zoology have served.

The Institute has visualized a broad approach to the scientific problems of the Lakes and has sought to bring together the facilities and interested personnel. The very size of the Lakes makes difficult and inefficient single handed and single minded approaches. As will be detailed later the first two major projects for which the Institute was responsible were cooperative efforts.

During the first five or six years the Institute was relatively inactive in terms of tangible accomplishments but much discussion and thought during those years has begun to bear fruit.

In 1948 and 1949 the Institute in cooperation with the U. S. Geological Survey carried out an extensive bottom sediment study in western Lake Erie. However, the present very active phase of the Institute's activity started with a summer Conference on the Upper Great Lakes held at the University of Michigan Biological Station in 1953. Largely as a result of this conference the Institute with the very generous support of the University administration embarked on a program to block out the major physical limnological setting of Lake Huron in the summer of 1954 and of Lake Michigan this (1955) summer. The 1954 Lake Huron study was carried out with the extensive cooperation of the Ontario Department of Lands and Forests. It will be reported in detail to you later in this meeting.

I am sure many of you heard the fine speeches yesterday by President Hatcher and General McNaughton on the Great Lakes and on the Seaway. Today we are going to have two panel discussions on problems relating to the Great Lakes. This morning's one is on the general topic of Water Quality and Water Usage of the Great Lakes. The discussion leader for this panel is Mr. Milton P. Adams, Executive Secretary of the Michigan Water Resources Commission, and I will turn this meeting over now to Mr. Adams to get this panel under way on this very interesting and important topic.

(Mr. Adams).... For those of us who heard those very fine talks yesterday, it is very clear the part that the Great Lakes and the St. Lawrence played in the development of this great Mid-West, but the subjects of at least two members of the panel this morning are going to deal with problems of these Great Lakes which, to my mind, are much more vital. We are going to deal with water qualities and the use of our Great Lakes' waters for the sustaining (if you please) of life itself in this area, and so far as industry is concerned, the use of these waters which has made possible the development of this area which navigation has served, is serving and will continue to serve as the Seaway is developed.

I do not know what these panel members will reveal, but I can lay just roughly the foundation for the area of our discussion this morning.

Michigan is in a particularly unique position, with four of the five Great Lakes providing part of its boundaries. We are talking about a total watershed area of 298,000 square miles of which nearly one-third, 95,000 square miles, constitutes the water surface of these five Great Lakes, Lake St. Clair and the connecting waters. With respect to certain phases of the discussion, we are talking about 3,120 miles of frontage that Michigan possesses on these Great Lakes, over one-third of the total which is recorded.

We are talking about a tremendous volume of water. We are dealing with an area in which the annual precipitation ranges from thirty-four inches per year in Lake Ontario to twenty-eight inches per year on Lake Superior, with an average over the entire Great Lakes watershed of a little over thirty-one inches. The main outlets to these Great Lakes in which we are particularly interested, the St. Clair River and the Detroit River, carry anywhere from 175,000 cubic feet per second to 200,000 cubic feet per second. This constitutes only about one-third of this total annual precipitation. If we don't have the normal amount of evaporation over this great area of 100,000 square miles, we have the situation which was created in 1952 when our lakes responded by jumping up, beyond, and above their normal height. That is

one of the problems that will be discussed here this afternoon; also the matter of erosion in the basin.

There are a number of problems that can't be covered on the panel today, and necessarily we are just going to touch upon those which are the most important ones. I want to say that, working with Dr. Sparrow, we have arranged these various fundamental uses on your programme, in the general order, as we see it of the necessity for cleanest water and the highest type of water. It is our plan to call upon each of these panel members to present their statements. Following that period, I think you will find them very co-operative in answering your questions, and we are very fortunate in having unusually well-qualified experts in the various lines with which we are going to deal.

WATER CONSERVATION

by
Stanley G. Fontanna
Dean, School of Natural Resources
University of Michigan

While the term "conservation" logically includes all uses, my remarks will be confined to uses for recreation and for the taking of fish and game.

Recreational Uses

Boating

Passenger boats including ore boats and freighters,
Sail boats,
Motor boats.

Of particular interest to small boats (both motor boats and sail boats) are the harbours of refuge being constructed at intervals along the lakes. In Michigan a special body called the Waterways Commission has been constituted for the purpose of building such harbours.

Bathing

All of the Great Lakes are used for this purpose, the use varying with the character of the beach and the temperature of the water. Best known, is the eastern shore of Lake Michigan with its fine sand beaches, including public beaches at the Dunes Park in Indiana, and Holland, Grand Haven and Muskegon Parks in Michigan. Affecting the quality of the bathing are such things as pollution and Great Lakes levels.

Scenery

People enjoy looking at the water and this is one of the big incentives for them to buy frontage on the big lakes. There is also a tendency to build highways adjacent to the lakes so that people may enjoy the scenery.

Climate

Another reason for people to seek the public beaches and to buy property on the Great Lakes is the cooler temperature which prevails during the summer.

Hunting and Fishing

Hunting

The bays and connecting waters of the Great Lakes furnish excellent waterfowl hunting. Notable for this use are Saginaw Bay in Lake Huron, the St. Clair Flats in Lake St. Clair, and the Lake Erie marshes. Affecting this use is water pollution, particularly oil.

Sport Fishing

This is enjoyed by thousands of people, fishing from docks and small boats. Perch and walleyed pike are caught generally and bass in selected spots. Muskellunge are found in Lake St. Clair and lake trout in Lake Superior. Pollution affects this use.

Commercial Fishing

This is a major industry, making millions of dollars. In pounds of fish produced the take of herring, smelt, chubs and carp now exceeds that of lake trout and whitefish. The lake trout has suffered drastically from the sea lamprey in lakes Michigan and Huron so that the take is largely in Lake Superior. The States, the Federal Government, and the Canadian Government are working co-operatively to do away with lampreys, with some evidence of success.

WATER QUALITY
AND WATER USAGE OF THE GREAT LAKES
PUBLIC WATER SUPPLIES

by
L. G. Lenhardt,
General Manager, Detroit Water Board

The Great Lakes represent perhaps this continent's greatest natural resource. With an area of more than 100,000 square miles, they have been estimated to contain about one-half the world's available supply of fresh water. With their unexcelled facilities for low-cost transportation, their ameliorating effect on climate, the tremendous resources around their perimeters, and an inexhaustible supply of water, they have made possible the vast industrial heartland which has developed around them.

From the standpoint of public water supply, the natural waters of the Great Lakes are of excellent quality (Table A). They have moderate characteristics and are readily amenable to treatment for special purposes. Hardness varies from a low of 50 in Lake Superior to a high of 125 p.p.m. in Lake Erie. The hardness is so favourable that only about five per cent of the public water supplies drawing water from the Lakes are softened. The pH of 7.5 in Lake Superior is the lowest, with the others ranging from a pH of 8.1 to 8.3, almost ideal. Turbidities, generally, have been low, so that for years municipal supplies delivered unsettled water to their consumers with but little complaint. Indeed, a number of communities still pump lake water to their mains without any treatment but chlorination.

By force of circumstances, the same lakes from which we obtain our public water supplies must also serve as the receiving waters for the entire drainage area. The storm water of streams, ditches and storm drains, with tons of silt and dirt, washes into them. Whether treated or not, the sewage of millions of people is finally discharged into the Lakes. The wastes from thousands of industrial plants must ultimately enter the receiving waters. The result is, despite all that has been done to remedy conditions in the past, public water supplies have either been forced to install treatment facilities of some kind or to expand existing facilities.

To ascertain the status of water treatment on the Great Lakes, we solicited the aid of the Health Department engineers of the eight states of this country which border thereon, as well as the Province of Ontario. They supplied us with lists of all municipalities and plants which use the Great Lakes and their connecting waters as a source (Table B). Of the questionnaires sent out to the 157 plant superintendents, 122 replies, representing a population of 14,750,799 were received. The 78 percent return is most unusual and betokens the interest of water plant operators.

Seventy-five percent of these plants, representing 76 percent of the population, clarify their water by coagulation and filtration. All use chlorination or some form of disinfection. Sixty-five percent of the population use water processed with activated carbon and 27 percent have their water treated with ammonia. These last figures are significant in betokening taste and odour problems.

Thirty-one percent of the plants, representing 63 percent of the population, report treatment problems due to industrial wastes. Only 22 percent of the plants, representing 29 percent of the population, report problems due to domestic sewage pollution. Fifty-five percent of the population are troubled with tastes and odours due to industrial wastes whereas 48 percent ascribe such troubles to algae.

It is interesting to note that more than 11 million people on the Great Lakes are now supplied with filtered water, whereas 50 years ago not a major city was so supplied. It has only been about ten years since Chicago received its first filtered water. Waterborne typhoid and cholera epidemics on the Lakes seem now a thing of the past. Only 22 percent of the plants reported trouble due to domestic sewage and apparently their conditions were safely handled, since no epidemics occurred. Disinfection, no doubt, accounts for this happy showing. In other words, water treatment has come of age and the public water supplies of the Great Lakes are now all safe supplies.

The questionnaires also showed, unmistakeably, that treatment of municipal wastes has also made great strides. A census of 30 years ago would, no doubt, have shown a much greater percentage of difficulties with domestic wastes than the 22 percent reported. Some of this progress in sewage treatment has been brought about by self-interest in protecting their own water supplies, such as at Chicago, Milwaukee, and Cleveland. Some cities, such as Detroit, were motivated primarily by the responsibility of being a good neighbour. But a major share of the credit for progress must go to those officials of the various states who have fought the battle of clean streams and waters (such as your Chairman) in which they were aided and abetted by conservationists, sportsmen, and those representing public water supplies.

Industrial wastes remain a problem. Despite super-chlorination, chlorine dioxide, activated carbon and ammonia treatments, some 55 percent of the population around the Lakes were plagued with tastes and odours in their water supplies, due to industrial wastes. In other words, despite a large increase in numbers of water treatment plants and a great improvement in treatment processing, industrial pollution is a problem which seems to be increasing. With the manifold products from the many industries it is apparent there can be no single, simple solution. And yet it is a problem which must be solved. There is nothing which brings a public water supply into such disrepute

Table A

CONDENSED CHEMICAL ANALYSES OF GREAT LAKES WATERS

	Total Alkalinity	Total Solids	Calcium (Ca)	Magnesium (Mg)	Carbonate Hardness (as $CaCO_3$)	Non-Carbonate Hardness (as $CaCO_3$)	pH
Lake Superior	45	57	14	4	50	5	7.5
Lake Michigan	110	150	32	10	120	10	8.2
Lake Huron	90	105	22	8	100	10	8.1
Lake Erie	100	150	35	9	125	25	8.2
Lake Ontario	110	165	37	7	123	--	8.3

(Analyses in Parts per Million)

Table B

Tabulation Based on Number of Great Lakes Water Treatment Plants Reporting

Total of 122

	Treatment Problems Caused By							Treatment Processes Used							
						Taste & Odor Caused By									
	Turbidity	Colour	Domestic Sewage	Industrial Waste	Plankton	Algae	Indus-trial Waste	Pre-Chlorine	Post-Chlorine	Chlorine Dioxide	Coagulation & Filtration	Softening	Activated Carbon	Ammonia	Others
Number	64	7	27	38	35	48	38	100	81	12	92	6	56	24	23
%	52	6	22	31	29	39	31	82	66	10	75	5	46	20	19

Tabulation Based on Population Served by Treatment Plants Reporting

Total of 14,750,799

	Turbidity	Colour	Domestic Sewage	Industrial Waste	Plankton	Algae	Indus-trial Waste	Pre-Chlorine	Post-Chlorine	Chlorine Dioxide	Coagulation & Filtration	Softening	Activated Carbon	Ammonia	Others
Number	9,538,826	103,500	4,279,290	9,227,714	7,373,714	7,082,614	8,191,489	13,945,310	8,972,583	1,541,783	11,199,482	787,400	9,537,814	3,987,414	1,472,000
%	65	1	29	63	50	48	55	94	61	10	76	5	65	27	10

as a foul-tasting water. A constant, unremitting fight must be waged against such pollution. It is strongly urged that the Michigan practice be followed in requiring new users of streams for waste disposal to show that they will not harm the receiving waters. Not only does industrial pollution cause difficulty in operation to public water supplies, but the expense connected with it is considerable, both as to operation and capital cost. It is difficult for the speaker to understand any justification for the public shouldering any part of the cost of operating a private enterprise as they do when compelled to protect themselves against the discharges from industrial plants.

However, there are signs of progress. The International Joint Commission has adopted standards as to pollution of receiving waters which, if followed, would eliminate problems of both municipal and industrial pollution. These standards were adopted pursuant to the Treaty of 1909, wherein both the United States and Canada convenanted and agreed not to harm each other's waters. While this has not been implemented by Canada as regards municipal sewage, there has been some progress on industrial pollution. The adoption of the I. J. C. standards throughout the Great Lakes would be a great step forward.

The speaker has often been asked as to why cities on the Great Lakes do not obtain a source of water supply free from contamination, man-made or otherwise, by going far upstream. Outside of staggering costs, there is another good answer. If laws and treaties are not followed and obeyed, no place on the Great Lakes is a safe source of supply.

INDUSTRIAL USAGE OF WATER,
INCLUDING THERMALLY-DEVELOPED POWER

by
Vincent S. Madison,
Director of Areas Development,
Detroit Edison Company

Thermal power plants have three basic uses for water.

We require water for the use of the employees. This water must, of course, be safe and potable. In four of our power plants, we purchase water for personal use from the cities in which our plants are located. In the case of our new St. Clair plant, we took over the operation of a township water works in order to assure us of an adequate supply, and resold to the residence users. This water use is moderate since employees in power plants range from 100 to 400 people.

Industry's most critical requirement for water of the highest quality is another use of the thermal power plant. This cut-away section (diagram shown) of the steam turbine illustrates this water requirement. In this section of the turbine, we have steam at 1,000 lb. pressure at 1,000 degrees Fahrenheit. This 1,000 kw. turbine uses water in the form of steam. It uses 850,000 lb. (or 102,000 gallons) of water per hour to generate 100,000 kwh. This water must be completely free of all minerals. Our treatment is by ion exchange. In condensing this steam to water, the most spectacular use of water becomes apparent.

Live steam in the turbine must be converted from the vapour phase to the liquid phase so it can be pumped back into the boiler. Steam passing around the tubes of this condenser immediately changes to liquid because of the relatively low temperature of the cooling water pumped through the tubes.

Detroit Edison pumps about two billion gallons of water per day for this purpose in our five plants. This is approximately 4-1/2 times as much water as Mr. Lenhardt pumps for the City of Detroit. When discharged from the power plant, this water is of a better quality than when it entered. We remove floating materials and solids by screening and with chlorinating prevent the formation of algae in the condenser tubes.

Throughout the nation, it is estimated that over 40% of industrial water requirements are used mainly for cooling and condensing purposes in the steam generation of electricity. Steam generation of electricity is the largest single user of industrial water. Steel production uses approximately 16%, petroleum refining 9%, pulp and paper 5%, and miscellaneous industries account for remaining 26%.

Of course, hydro electric plants use vast amounts of falling water and require six times as much water as all other uses combined, and produce only about 25% of the country's electrical energy.

Industrial uses of water in the United States account for nearly five times as much water as is used by homes, or about 80 billion gallons per day. The steel industry and allied products, being the second largest user, combined with water use for steam power, totalled about 50 billion gallons of water per day in 1950.

The nation-wide average cost of industrial water may average between four and five cents per 1,000 gallons. More than two-thirds of the entire national water bill is borne by industry. A single large steel mill may require as much as 500 million gallons per day—enough water to supply all normal requirements of a city of several million population. About 25% of the water for industrial use is purchased, while the remaining 75% is produced largely from ground water resources.

It may be of interest to you to know: that it requires 120 gallons of water to produce one gallon of 100-proof alcohol; that it takes 15,000 gallons of water to make an automobile; 270 tons of water to make one ton of steel; 2500 tons of water to make one ton of hydrogen or a ton of synthetic rubber and that it takes 200 to 250 gallons per day per hospital bed.

Jack R. Barnes, the Consulting Ground Water Hydrologist who prepared the chapter on water in his report to the President's Materials Policy Commission, concluded that by 1975 water supply might be the most important factor affecting industrial plant location. During World War II plans for building 300 industrial or military establishments had to be abandoned or modified due to inadequate water supply. Our use in 1975 is estimated to approach 350 billion gallons per day as compared with 185 billion gallons per day in 1950. Since 1900 our use has increased from four to six times, while the population has little more than doubled. The estimated water use in 1975 indicates a rate of gain close to three times as great as the expected population increase.

GREAT LAKES NAVIGATION

by
Harley F. Lawhead,[1]
U. S. Corps of Engineers

Introductory

The notable influx of immigrants to the region of the Great Lakes, which occurred in the 1820's and 1830's, depended to a considerable degree upon Great Lakes navigation as a means of transportation. The migrations to the region from Europe and the Atlantic seaboard were accelerated by the opening of the Erie Canal in 1826, which linked Lake Erie with the Hudson River and New York City.

The early explorers and settlers found in the Great Lakes a convenient means of access to this area. They also discovered that the lands adjoining the Lakes abounded in natural resources: fur-bearing animals; white pine and other valuable timbers; many areas of fertile farm land; and minerals. But the existence of iron ore in the Lake Superior region, coal not far from the southeastern and the southern limits of Lakes Erie and Michigan, and limestone along the northern shores of Lakes Huron and Michigan—the existence of these resources in those situations with respect to the Lakes—basic materials which must be brought together for the production of iron and steel, assured the development of navigation on the Lakes to the point where they have become known as the world's greatest inland waterway.

In their natural state, the Great Lakes and their connecting rivers were navigable to a considerable extent by the vessels in early use. However, there were obstructions to through navigation, particularly at certain locations in the connecting rivers; and there were few natural harbours on the Lakes. The rapids of the St. Mary's River at Sault Ste. Marie effectively blocked through navigation from the lower lakes to Lake Superior. The mouths of rivers discharging their flows into the Great Lakes, such as the Chicago River in Illinois, the Maumee River in Ohio, and the Saginaw River in Michigan, provided the logical situation for many of the harbours of the Great Lakes. With few exceptions, however, these have required improvement to provide adequate depths for navigation or adequate protection from lake storms.

I am proud to be able to say that my native State of Michigan made the earliest and most important contribution toward the furtherance of commercial navigation on the Great Lakes. One hundred years ago, this month, the first ship canal and lock were opened to traffic. These were constructed by the State of Michigan. As an engineer for the U. S. Corps of Engineers, I am also proud to be able to tell you that Captain Augustus Canfield, an officer of the Topographical Engineers, which was later combined with the Corps, prepared for the State the final construction plans for this lock.

Surveys by the Topographical and Corps of Engineers for navigation charts and improvements commenced in 1841. The State Lock was transferred to the Federal Government and turned over to the Corps of Engineers in 1881. Throughout the development of facilities for better, safer and ever-increasing navigation on the Great Lakes, the Corps of Engineers has played a most responsible part in its assigned mission of studying the economics of, preparing the plans for, and supervising the construction of river and harbour improvements. So much for our introductory remarks.

Growth of Great Lakes Commerce

I note that one of the objectives of the Great Lakes Research Institute is to bring before the public information pertaining to these Lakes. Certainly, from the viewpoint of navigation on them, there is no better way of gaining a knowledge of the importance of such navigation than to consider the growth of the Great Lakes commerce. A convenient source of information is the published record of tonnages passing through the locks at Sault Ste. Marie. The following figures, total tonnages by ten-year increments, illustrate the growth of commerce during the past century:

1855-64	1,200,000
1865-74	4,800,000
1875-84	15,000,000
1885-94	80,000,000
1895-1904	253,000,000
1905-14	577,000,000
1915-24	764,000,000
1925-34	651,000,000
1935-44	870,000,000
1945-54	1,073,000,000
Total for 100 years	4,289,000,000

Roughly, and more particularly for the later years, 75% of these totals represent iron ore shipped to lower lake ports for processing into finished steel products. Other bulk commodities, comprising a large part of the remainder, include coal, wheat, grains other than wheat, petroleum products, and stone. In 1855, the first partial year for the State Lock, the total commerce was 14,503 tons. In that year, the tonnage of copper was double the tonnage of iron ore and, while no wheat passed through the lock, some 10,000 barrels of flour were shipped.

[1] Vice Col. A. C. Nauman, District Engineer, U. S. Corps of Engineers

A closer look at the statistics shows that nearly 25% of the tonnage for the first 100 years of operation of the locks was carried during the ten-year period from 1945 to 1954, with an all-time record being established in 1953 when 128 million tons of commerce passed through them. True, that during this record year a large portion of the demand on the steel industry was brought about by heavy requirements of the military. However, to supply only peacetime demands of the nation, iron ore to date this year is being carried at about the same rate as in the record year of 1953. Tonnages through the locks do not, of course, include all of commerce on the Lakes, but they do provide a reliable barometer for recording its growth.

The importance of waterborne commerce to the economy of the United States, and especially to that of Michigan and the neighboring areas, is not often quickly recognized. Without the availability of the Great Lakes Waterway, the mode of living in the United States would conceivably approach that in other countries of the world where basic commodities of industry such as iron ore, limestone and coal, would necessarily be moved overland. You can imagine the congestion on midwestern rail routes along, if approximately 100 million tons of iron ore were to be moved in one year—realizing that two 100-car train loads of ore represent but one ship load. The rail capacities needed for the movement of stone and coal in the amounts required to provess iron ore to finished steel, as you can readily see, would result in little rail capacity for the movement of other bulk commodities such as cement, wheat and petroleum, let alone finished consumer products.

If it were possible to ship the same volume of bulk commodities overland, the costs of items to which we are accustomed in our every day life would be noticeably higher. Also, these items that we consider common would not only cost more but the quantities available would be appreciably less. And too—there is the question of national defense. Without the Great Lakes Waterway, it is doubtful whether it would have been possible to have accomplished what we in the United States did in World War II and during the Korean War in the way of production of arms even with the total stoppage of flow of finished hard goods to the civilian economy.

Lake Vessels

In view of the importance of the lake commerce, it is not surprising that the fleet of lake vessels has undergone considerable development over the years. The characteristic long and narrow shape of the ships, with pilot house forward, engine room aft, and cargo hold in between, was in use as early as the 1880's. In 1903, the first steamer with hatches spaced on 12-foot centers appeared on the Lakes. Several years ago, the spacing was changed from 12 to 24 feet. However, a standardized hatch spacing permitted the correlation of loading and unloading equipment with the ships.

The newer freighters have been made larger and faster, and during the last 50 years or so, there has been a trend toward a smaller number of vessels in the bulk-commodity service. In 1900, there were some 800 freighters, 56 of which were 400 feet or somewhat longer in length. At the present time, there are fewer than 600, several of which are over 700 feet in length. An example of the newer freighters, the GEORGE M. HUMPHREY, is 710 feet in length, 75 feet in breadth, has a maximum draft of 26-1/2 feet and a maximum carrying capacity of over 23,000 tons. A few years ago, the speed of the freighters was about 12 miles an hour. Some of the newer vessels can make 16 miles an hour or better.

The channels and harbours have also been improved over the years. Time does not allow a complete step-by-step discussion of all the improvements which have taken place since the completion of the State Lock. However, a brief outline of the projects presently in effect appears in order.

Present Channel and Harbour Facilities

First let us consider the channel facilities, which perhaps are of particular interest to Michigan and are important to the bulk-commodity commerce on the lakes. The existing project for the Great Lakes Connecting Channels between Lake Superior and Lake Erie, and to Lake Michigan, is substantially complete and provides for downbound channels with depths of 25 feet, when the lake stages are at their established datum planes; and where separate upbound channels are provided, depths of 21 feet. The separate upbound channels have been made less deep, since in this commerce the freighters generally come down from Lake Superior loaded with heavy iron ore and return upstream either light of cargo or with a cargo of lesser specific gravity.

In general, the open lakes are deep enough for the needs of navigation. In certain reaches of the connecting rivers, however, the channels have required deepening. Starting at Lake Superior and proceeding downstream, the improved reaches are as follows:

- Upper St. Marys River
  - Round Island Shoals
  - Pt. Louise to Brush Point
  - Vidal Shoals
- St. Marys Falls Canal
  - Locks and approach channels
- Lower St. Marys River
  - Bayfield Shoal
  - Little Rapids Cut
  - Lake Nicolet Channel
  - Middle and West Neebish Channels
    - (Middle Neebish upbound)
    - (West Neebish downbound)
  - Lake Munuscong Channel
  - Crab Island Shoal (near Detour)
- Vicinity of Straits of Mackinac
  - Poe Reef Shoal (near Cheboygan)
  - Mackinac Island Channel
  - Grays Reef Passage (northeast of Beaver Island)
- St. Clair River
  - Foot of Lake Huron Channel
  - Scattered shoal areas - Port Huron to St. Clair
  - Marine City Shoal
  - Roberts Landing Shoal
  - Head of Russell Island Shoal
  - South Channel of St. Clair Flats

Lake St. Clair
- St. Clair Flats Canal
- Channel through Lake St. Clair

Detroit River
- Head of Detroit River Channel
- Fighting Island Channel
- Ballards Reef Channel
- Livingstone Channel (downbound)
- Amherstburg Channel (upbound)
- Channels to deep water in Lake Erie

The foregoing channels, linking all of the lakes except Ontario, have been important to the bulk-commodity commerce. In 1932, the Canadian Government opened the present Welland Ship Canal to traffic. This canal, which overcomes the 326-foot drop between the level of Lake Erie and the level of Lake Ontario by means of seven lift locks plus one guard lock and has a minimum channel depth of about 24 feet, provides a deep-draft link to Lake Ontario. There are also the St. Lawrence River Canals which link Lake Ontario with tidewater at Montreal, with controlling depths of about 14 feet; and the New York State Barge Canal, connecting Lakes Erie and Ontario with the Hudson River; and the Chicago Sanitary and Ship Canal, connecting Lake Michigan with the Mississippi River. Both of the latter have depths for barge traffic only.

Along the shores of Michigan, there are some 70 localities which are either harbours or ports, ranging from harbours for light-draft vessels, such as fishing and pleasure craft, up to deep-draft harbours for the bulk-commodity commerce. Seventeen of these have depths of 20 feet or more and seven of 24 feet or more. Not all of them have been improved by the Federal Government. At the present time, there are 57 authorized harbour improvement projects in Michigan, 27 of which are completed, 17 of which are under way, and 13 of which have not yet been commenced. These include harbours of both light-draft and deep-draft categories.

There are many improved harbours in other states which are of prime importance to Michigan's industrial development. For example, hugh quantities of coal are shipped from Toledo to Detroit for use in the production of steel and electrical power.

Generally speaking, authorized harbour improvements are for breakwaters where needed, entrance channels and jetties, anchorage areas, and in the case of river harbours (such as that at Bay City and Saginaw), deepening of the river for some specified distance upstream from the mouth, and turning basins for the ships to turn around in. Wharfage and other port facilities, including deepening along the wharf faces, are provided by local interests.

Maintenance and Operation

With regard to maintenance and operation of the channels and locks, the task of the Corps of Engineers is one of those very important jobs which receives but little public notice so long as everything functions smoothly.

The connecting channels which make navigation possible from Lake Superior to Lake Erie are maintained under the jurisdiction of the U. S. Corps of Engineers. This requires regular maintenance operations to maintain project depths and a constant alert to ensure, insofar as is humanly possible, that nothing will interrupt this vital artery of commerce.

Outflows through the connecting channels from the Lakes above are generally clear and the amount of work required to maintain depths in considerable lengths of the streams is not large. This is substantially true for the upper reaches of the St. Marys, St. Clair and Detroit Rivers. However, there are localities in these channels which require a large amount of work. These include improved channels of the lower St. Marys River, particularly at angles in the channels; the South Channel through the St. Clair Flats and those at the lower end of the Detroit River, particularly where they extend into Lake Erie. Annual maintenance is required at the lower end of the Detroit River. The total annual cost of maintaining the connecting channels is about \$516,000.00.

Annual maintenance is also required at Saginaw, where the channel extends into Saginaw Bay; at Toledo, where the channel extends into Maumee Bay; and at River Rouge. For these localities, the estimated annual costs are \$100,000.00, \$354,000.00 and \$99,500.00 respectively.

At times in the past all of the channel depths were not in perfect balance for through navigation. This was due to the fact that an authorized improvement was not completed throughout the connecting channels, or that one lake was abnormally low with respect to the others. Such conditions have necessitated enforcement of draft regulations to ensure against groundings of ships in the more shallow reaches of restricted channels. This was particularly true in the late 1920's.

Recommended Improvements

We have developed briefly the importance of commerce on the Great Lakes and noted the trend toward larger ships. Furthermore, many of the older boats in the present fleet are approaching the end of their economic life and will soon need to be replaced. The demonstrated economy of the larger, faster boats assures that replacements will be of this type. Depths available in the present channels, except at extreme high lake levels, will not permit these newer boats to load to full allowable draft.

Realizing the inadequacy of the present connecting channels for the new fleet of lake bulk carriers and that legislation on the St. Lawrence Seaway then being considered would extend the 27-foot channel only to Lake Erie, both the House and the Senate by resolutions of their respective Public Works Committees in March and June 1953 directed the Board of Engineers for Rivers and Harbours to review the previous reports on the connecting channels to determine the advisability of further improvements of these channels, including consideration of providing depths of at least 27 feet. As a result of this directive, a review was made and report prepared and submitted by the Detroit District Engineer of the Corps of Engineers.

With the view of providing channel depths which would result in maximum benefits, the older concept of uniform channel depths was abandoned in favour of more uniform safe drafts for vessels. The subjects of channel depths and vessel drafts are sometimes confused in popular discussions of navigation improvements. Perhaps there should be a clarification.

In determining the channel depths for a new improvement, it is necessary that certain clearances be considered. Sufficient clearance must be provided under the keel of the vessel to permit it to move safely and at an efficient speed. Increased clearance should be provided for rock bottom over that for soft bottom because of the serious damage which would result to a vessel if it should strike ledge rock or boulders and also as a factor of safety against possibility of damage from fragments of rock or boulders which might be turned up by water action, to extend above the project depth plane during the periods between maintenance operations in the channel. Additional clearance must be provided in exposed areas, as compared to sheltered areas, since vessels are subject to vertical movement because of storm and wave action. It has been determined that the total clearance allowance should be 0.5 foot in sheltered channels with soft bottom, 1.5 feet in sheltered channels with hard bottom, and these allowances increased by 1.0 foot for corresponding channels in exposed areas.

In addition to the above clearances, an allowance must be made for the squat of a vessel when under way. Squat is defined as the increase in draft assumed by a vessel when under way over that when the vessel is at rest. This increases with vessel speed. For older vessels of the Great Lakes cargo fleet operating at slower speeds, an allowance of 1.0 foot for squat has been made in the past. However, with the newer vessels operating at greater speeds, additional allowance for squat is now necessary. Recent studies have been based on squat allowances varying up to a maximum of 2.0 feet in open river or lake channels.

Full consideration of these factors has resulted in the recommendation of a project that will provide for a safe vessel draft of 25.5 feet when the controlling lake is at its low water datum. This will necessitate construction of channels varying in depth from 27 to 30 feet. Such a project would be commensurate in depth with the St. Lawrence Seaway. Its cost of construction is estimated at this time to be approximately 110 million dollars.

A quick glance at this increase in available vessel draft may not seem significant. However, I should like to mention that for each one-inch increase in draft, an average bulk carrier may haul from 80 to 100 additional tons of iron ore.

Since at the time of the report, benefits resulting from the St. Lawrence Seaway could not be adequately evaluated, no attempt was made to use them in the economic analysis although it is certain that such benefits will accrue. Only the following conservative estimates of major items of commerce to be carried annually in the connecting channels for the period 1960 to 2010 were used:

Iron Ore	82,000,000	Tons
Coal.	66,000,000	"
Limestone . . .	35,000,000	"
Grain	5,800,000	"
Petroleum . . .	3,900,000	"
	192,700,000	"

The ratio of transportation savings to construction costs and annual maintenance over the projected 50-year life of the project is 1.78 to 1.

The proposed project has been approved by the Board of Engineers for Rivers and Harbours and the Chief of Engineers and is now before Congress for its consideration.

Interrelation With Other Usage of Lakes

And now before I close, I would like to say a few words about the interrelation of the navigational use of the Great Lakes with other beneficial uses. Such uses include public water supply, hydro-electric power production, industrial usage of water, commercial fishing, and recreational pursuits. In order that certain of these uses can be made, it is necessary that the quality of the water be maintained.

And too, it must be remembered that the Great Lakes are international waters, boundary waters between the two friendly countries of Canada and the United States. Therefore, usage by interests in one country may affect the rights of users in the other.

In the studies of proposed navigation improvements, such as that for the connecting channels which we discussed earlier, it is necessary to consider several of these factors. One segment of the improvements recommended involves a cut-off at the southeast bend of the St. Clair River to straighten the navigation channel. Since this cut-off would be almost entirely in Canadian territory, coordination with Canadian authorities and their approval is necessary before construction. Since it would traverse Indian lands, coordination with the Indians is also required.

In studies to determine compensation works in the lower Detroit River, which are required to offset the effect of channel enlargements on the river's discharge capacity and thus on the levels of the river and lakes upstream, consideration was given to possible effects on temperatures of water used for cooling at steam power plants due to reduction of flow rate in the Trenton Channel.

The studies determined that the recommended improvements would have no material effects of a permanent nature on water power, wildlife preservation, recreation, or public water supply. It was brought out at the public hearing by a representative of the Department of Water Supply of the City of Detroit, however, that during dredging operations, the City's intakes would be subjected to considerable increases in turbidity which would place an additional load on the treatment plant. He stated that the Department of Water Supply was not in opposition to the improvements, but asked that consideration be given to the timing of dredging operations so as to avoid this situation as much as possible during the period of heavy water usage.

The effect of the recommended improvements on rates of erosion or accretion on the shore lines near the channel outlets was also considered. Based on similar channel enlargements in the past, the improvements are not expected to have any effect on the shore lines.

As an assurance that such factors will not be overlooked, public hearings are held prior to the initiation of these studies and coordination with the adjoining states and with other Federal agencies is effected during the studies.

The operation of large vessels at excessive speeds

in confined areas, such as certain reaches of the St. Marys and St. Clair Rivers, throws waves against the river banks which may cause local inundation or bank erosion. The Secretary of the Army is empowered by the River and Harbour Act of August 18th, 1894, to establish speed regulations and has established such regulations requiring vessels of more than 500 gross tons to check their speed to 12 miles per hour in these localities.

Navigation is a very important use of the waters of the Great Lakes, but the Corps of Engineers is well aware that it is one of several beneficial and important uses. It is the policy of the Corps, in carrying out its assigned mission with regard to river and harbour improvements, to develop plans which recognize the rights of other users and plans which are coordinated with the other uses.

THE GREAT LAKES BASIN COMPACT

by
Nicholas V. Olds,
Assistant Attorney General,
State of Michigan

I wonder how many of us realize the breath-taking attributes of the Great Lakes area? It is impossible for me to equal the picture that was painted by Professor F. N. Menafee of the Engineering School of the University of Michigan at a Great Lakes Levels Conference held in Lansing, Michigan, on September 19th, 1951. Professor Menafee said:

"There is no spot in the world that combines so many necessary qualifications for successful progressive living by the human race as does the Great Lakes District of North America. In it we find invigorating climate, iron ore in great quantities, varied soil conditions, abundant rain fall, great agricultural areas, great cities, enormous timber tracts, thousands of square miles of recreational areas, and in the midst of it all an aggregation of five connecting deep fresh water lakes which provide cheap transportation for raw materials and fabricated products totaling more than all the foreign tonnage of all the sea ports in the United States."

"The five lakes cover as much of the earth's surface as continental Portugal, Switzerland, Belgium, Netherlands, and Denmark. Their 95,160 square miles constitute one-third of the fresh water area of the globe, and almost twice the total of 53,015 square miles of the lakes for the remainder of the United States. The land surface within the rainfall catchment area, which was shown in the map on the screen here by Mr. Lawhead, is 202,920 square miles in extent, making the lakes themselves a drainage area of 298,000 square miles, almost one-third of which is lake surface. An ideal situation from the standpoint of the engineer for what we call 'impounding basins.' "

"The casual observer might be led to think that with all this water there never should be any trouble about water—too much or too little in the Great Lakes or in their connecting channels and inlets. Such is not the case. The waters of these lakes form one of the world's greatest transportation systems, most of which consists of hauling iron ore and grain from Duluth, Minnesota, at the extreme west end of Lake Superior to the cities on the lower lakes and hauling coal and other bulk commodities back."

"Many years ago it was clear that these international waters were an unparalleled natural resource to both Canada and the United States. That potential use and development would bring into play millions of invested dollars on both sides of the border, and wise statesmen also foresaw endless possibilities of international complications and controversy unless coordinated controls by both countries could be established. In anticipation of the need for it, the two governments, after extended exchanges of opinion, joined in the creation of a body known as the International Joint Commission, for among other things, the investigation, which if not capably and authoritatively handled could develop into a major controversy with 'irritated local interests fanning flames of international misunderstanding'."

That there would be a diversity and conflict of uses which were expected to be made of these waters was recognized in the Boundary Waters Treaty of 1909 between Canada and the United States, for that treaty provides for the following priority of uses of these waters:

1. Uses for domestic and sanitary purposes.
2. Uses for navigation, including the service of canals for the purposes of navigation.
3. Uses for power and for irrigation purposes.

On May 9th, 1952, the Council of State Governments held a meeting at Chicago of the Great Lakes states for the purpose of considering what to do with the problems that beset them arising out of high stages of water levels then existing.

At that meeting it was resolved by the representatives of the Great Lakes states present that the governor of each state should appoint representatives to a continuing committee which would concern itself with a study of the problems of the Great Lakes and make recommendations on probable solutions.

During the early days of Michigan's 1954 legislative session, I was asked by the Commission on Interstate Co-operation to discuss a difficult controversy existing between Michigan and Wisconsin over regulation of the commercial fisheries in Lake Michigan waters. During the discussion, we reviewed many other problems that exist among the Great Lakes states arising out of the use of these waters. The commission instructed me to draft a statute to be proposed to our legislature, authorizing the State of Michigan to enter into a consultative compact with the other Great Lakes states. Such an act was introduced and passed by Michigan's legislature.

Shortly after the passage of this act, we asked the Council of State Governments to call a conference of representatives of all the Great Lakes States, including representatives from the province of Ontario, the government of Canada and interested federal agencies. Such a conference was held in Chicago on August 26th, 1954, at which Michigan's delegation presented its views to the other Great Lakes states concerning the need for some organization of the Great Lakes states which had official status and sanction. At the conference, I had the privilege of presenting a statement on the title "Why a Great Lakes Compact?", in which was discussed the legal and administrative aspects of such an organization. The upshot of this conference was the adoption of a resolution by the unanimous vote of representatives of all of the Great Lakes states, in favour of the formation of such an organization and requesting the Council of State Governments to draw a

tentative and preliminary draft of a suitable Great Lakes basin compact. Upon the preparation of the draft of the compact, a meeting was held at the offices of the Council of State Governments in Chicago on November 8th and 9th, 1954, by representatives of all of the Great Lakes states for a review and revision of the proposed draft. This group of state officials worked diligently and harmoniously on this draft, making many revisions and amendments. The draft of the compact as revised and amended was again presented to representatives of the Great Lakes states at the meeting of the general assembly of the Council of State Governments in Chicago on December 1st, 1954; at which time minor revisions and amendments were made and agreed upon. The draft of the Great Lakes basin compact attached is as it was approved by these representatives of the Great Lakes states at this last meeting.

The legal basis for the making of compacts among the states is found in Article 2, Section 10 of the Constitution of the United States, the pertinent part of which reads:

> "No state shall, without the consent of Congress....... enter into any agreement or compact with another state, or with a foreign power.... "

Although this language is in the negative, it constitutes merely a restraint on the powers that the colonies inherently had and used for the making of agreements among themselves prior to the adoption of the Constitution. The language is an apparent recognition of the continued use of that power and has been liberally construed by the Supreme Court of the United States in favour of the formation of such compacts.

Already four states have ratified the Compact, namely, Michigan, Indiana, Wisconsin and Minnesota.[1] Other state legislatures as of May 24th of this year have done the following:

Illinois:	H. B. 983 was introduced on May 5th and has been referred to the Executive Committee.
New York:	No introduction of the Compact.
Ohio:	Identical bills, H. B. 146 and S. B. 103 have been introduced.
Pennsylvania:	S. B. 216 has been referred to the Committee on State Government and has been approved by the Commission of Interstate Cooperation.

In accordance with Article II, Section a, the Compact shall go into force when it has been enacted by the legislatures of four of the eight Great Lakes states. Since four states have done so, the ratifying states may now come together and bring into existence the Great Lakes Commission. I understand that the Council of State Governments is holding a meeting in July at Mackinac Island and that arrangements are being made for the calling together of the commissioners of the four ratifying states for the purpose of discussing organization plans. It is expected that the non-ratifying states will also be invited to participate unofficially.

The Provinces of Ontario and Quebec under Section b, Article II may become parties to the Compact. They were invited to the various meetings at which the Compact was discussed and the Canadian government sent a representative to such meetings. Undoubtedly, they will be invited to attend future meetings as unofficial participants and observers.

The offices and services of the Council of State Governments have been very useful in bringing together the Great Lakes states to discuss the Compact idea, first in Chicago on August 26th, 1954, and then at subsequent meetings in November and December, at which the detailed provisions of the Compact were discussed and agreed upon by a drafting committee composed of representatives from each of the Great Lakes states. It should be pointed out that this has been a signal service rendered by the Council of State Governments.

At the first meeting on August 26th, 1954, I delivered a paper entitled, "Why a Great Lakes Compact?" to the representatives of the Great Lakes states. After the discussion which ensued, a resolution was unanimously passed approving the formation of such a Compact and requesting the Council of State Governments to prepare a tentative draft of the proposed Compact to be submitted to the drafting committee composed of representatives of all of the Great Lakes states. A copy of this resolution as well as an editorial which appeared in the Detroit Times on December 27, 1954, were attached to a paper which I delivered on January 6th, 1955, entitled "Proposed Compact of the Great Lakes States" at the third annual meeting of the Great Lakes Industrial Development Council at its meeting in South Bend, Indiana. These papers are available to you on request.

The following is a brief summary of the contents of the Compact:

<u>Article I</u> defines the purposes. Perforce these purposes are broad and general in character. They indicate that the objective of the Compact is "to promote the orderly, integrated and comprehensive development, use and conservation of the water resources of the Great Lakes Basin."

<u>Article II</u>. This article provides that whenever four of the eight Great Lakes states have adopted the Compact, it shall go into effect and that the Provinces of Ontario and Quebec may join as members.

<u>Article III</u> delineates the Great Lakes Basin which includes all of the Great Lakes, the St. Lawrence River, together with the tributaries which flow into and comprise a part of the Great Lakes watershed.

<u>Article IV</u> sets up the organization of the Great Lakes Commission, provides for the employment of an executive director, describing his duties and other items having to do with the management of the business of the commission.

<u>Article V</u> sets up the method of financing the work of the Commission.

<u>Article VI</u> describes the powers to be exercised by the Commission.

It should be noted that the Commission is not vested with any policing or enforcement powers. The central idea of the Compact was that the Commission should act purely in a recommendatory capacity. There are those who would say that this is insufficient. However, I need not remind you that it would have been

[1]Legislation ratifying the Compact was approved in Illinois on July 14, 1955, and in Pennsylvania on March 22, 1956. The Great Lakes Commission was organized on December 12, 1955, and has established its headquarters on the Campus of the University of Michigan in Ann Arbor.

impossible to have had the states agree to the formation of a Commission vested with powers to enforce its decisions. We should not minimize the importance of recommendations, because it is surprising how effective and how powerful recommendations are. Congressional and legislative committees recommend legislation and we all know that it is almost impossible to secure legislation which has not received the approval of an appropriate committee. In the administrative branch of the government there are a few top-level officials who have the authority to make decisions, but who depend on the recommendations of subordinates in the making of and implementing their decisions. Lawyers who appear in court on opposite sides of the case merely recommend to both the court and the jury what the decision or verdict should be. Instances of this kind could be enumerated ad infinitum. It was the concensus among all those who participated in the drafting of this Compact that the recommendations of this Commission should be a potent force in securing the action or decisions needed.

Article VII sets forth the various actions which party states agree to consider upon recommendation of the Commission. They include such items as establishment of lake levels, measures of controlling pollution, beach erosion, flood control and shore inundation, uniformity in navigation regulations and fishing laws and regulations, and others therein enumerated.

Article VIII provides that the Compact shall continue in force and be binding upon each party state unless renounced by an act of the legislature, but that the renunciation shall not become effective until six months' notice shall have been officially communicated.

Article IX is entitled CONSTRUCTION AND SEVERABILITY and is purely a legally technical article which is usually contained in many statutes of our states.

In Michigan, the act ratifying the Compact makes provision for five commissioners who shall consist of the Attorney General, the Director of Conservation, the Executive Secretary of the Water Resources Commission and two other representatives to be appointed by the Governor who shall come from groups or organizations interested in or affected by the Great Lakes. Since the Compact provides that each state shall designate not less than three nor more than five members and that each state shall have three votes, each of our commissioners shall have three-fifths of a vote. The legislators and state officials who comprise our Commission on Interstate Co-operation desire that our representation on the Commission be broadly based and that the majority be administrative officials who would have continuity of tenure and technical competence in handling the affairs of the Commission. However, each state is permitted in the Compact to decide for itself what the composition of its representation on the Commission shall consist of.

There are those who might say that this is just another organization cooked up to add to the number of public bodies which now exist. What do such critics have to offer in its place? Certainly the individual states cannot unilaterally deal effectively and intelligently with the enormous resources that comprise this great fresh water basin. The State Department surely cannot control these resources excepting by treaty with Canada. For over 15 years, a general fisheries treaty lay in the Senate unratified until it was recently withdrawn by the President and replaced by a treaty of limited scope signed last September. According to press reports, this was just ratified by the Senate.

Unless the individual states have the good sense to bring about an organization of their own making which will function effectively and intelligently and efficiently in dealing with the resources of this basin, little by little the Federal government will take over to the exclusion of the states. However, by taking the leadership in finding satisfactory and adequate solutions to the many problems which inevitably arise out of the multiple uses which will be made of the water resources of this basin, the states by joint and common action will so occupy the field that the need for federal intervention will not be required. The use by the states of the Compact authority contained in the constitution has grown considerably during the past 25 years. It has proved to be a satisfactory mechanism which the states may utilize for solving regional problems and in the management of resources in which they have common or correlative interests. Those of us who have worked in bringing about the Great Lakes Basin Compact fervently hope that at long last the Great Lakes states will have found and created a medium which will serve each and all of them in their efforts to make the best and highest utilization of the water resources of this vast fresh water basin—the largest of its kind in the whole world.

DISCUSSION

LIFTON: Does the Detroit Edison Company have any plans for an atomic generator?

MADISON: It is not generally recognized that an atomic energy power plant is no different from any other power plant, except in just one respect—we do not have a boiler that burns coal any more. Otherwise there is no difference. Instead of a boiler which generates steam, we have a reactor. We use a suitable low temperature, high heat-conducting material, such as liquid sodium or other efficient conducting material which in small volume delivers good quantities of heat to a flash boiler. The rest is all the same. The turbine requires steam of a high quality and it requires the same quantities of condenser cooling water per 1,000 kw. of generating capacity that a steam plant does.

LIFTON: Does the Detroit Edison Company plan to develop the property at Harbor Beach?

MADISON: Yes, we do plan to develop the Harbor Beach site and will eventually use it, but

it is strictly a business affair—a matter of pure economics. We must locate our power plants in a place where they will generate the greatest amount of energy, the greatest block of load, at the lowest cost. Obviously Harbor Beach is away up at the top of our territory in an area where load density is at present small. The factors are, as the load builds up, the need for power will increase, but I would be surprised if the next new installation will be there.

SPARROW: What plans, if any, are being made f the disposition of atomic wastes from such an installation?

MADISON: I am not too familiar with the problems of the breeder reactor type of power plant. I do know that most of the wastes are considered to be saleable. It is a lower form of atomic energy which could be used perhaps for destruction, maybe for bombs or for the production of isotopes. Disposal of wastes is entirely a matter of economics.

LEVELS OF THE GREAT LAKES

by
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Levels of the Great Lakes affect either directly or indirectly all residents of the lakes basin. Those who live or work along the lake shores are affected directly by high or low water, and those who reside in the interior of the basin are affected indirectly by changes in the economy of the region brought about by changes in lake levels.

Those primarily concerned with fluctuations in lake levels consist of three groups; navigation interests, hydroelectric power interests and riparian owners. Navigation people prefer periods of high levels in order to load their vessels to the deepest available safe draft, with only the minor disadvantage of having to reduce speed in the connecting rivers to avoid property damage, power interests desire uniform river flow with large enough lake storage capacity to insure a high minimum river flow, and riparian owners want an intermediate stage; not high enough to cause damage from erosion and flooding, and not low enough to make marine structures unusable.

The U. S. Lake Survey has for many years served all three of these interests with reliable lake level information. Reliable levels at scattered intervals are available on Lake Ontario since 1815, Lake Erie since 1819, and Lake Michigan since 1836. Many more early records were obtained by laymen interested in lake levels, but unfortunately, few were referred to permanent bench marks. The best of the early gages were those whose elevations were referred to the sills of navigation locks. Good continuous values are on record for all lakes since the Lake Survey first established a series of gages in 1859, thus providing a 95 year span for those who wish to study lake level fluctuations. The data are now being obtained from gages at 45 sites on the lakes and outflow rivers, and distributed as hourly, daily or monthly mean values. Distributed similarly are the river outflows derived from lake and river stage relationships.

The water surface elevations of the Great Lakes are based upon Mean Tide at New York as established by lines of precise levels run from tide water to Lake Ontario, and between Lakes Ontario and Erie, Erie and Huron, and Huron and Superior. Transfers of levels are made on the lakes by a comparison of gage readings over a period of a month or more, it being assumed that the average surface of each lake is level. It has been found that elevations can be transferred long distances by water-level comparison with a much greater accuracy than can be secured by the best instrumental levels on land. The first accurate determination of the elevations of the Great Lakes was made in 1875, and a second determination was made in 1898-1901 with more precise instruments. Since 1934 all of the level lines between the lakes have been re-run, but no new correction to sea level has been made. At the present time the U. S. Lake Survey is engaged in cooperative studies with the Canadian Technical Agencies aimed at establishing a common datum based on mean tide in the Gulf of St. Lawrence for referencing all water levels published on the Great Lakes.

Levels of the Great Lakes fluctuate from year to year and from month to month during each year. In addition, the stages at any given locality vary from day to day and even from hour to hour. These fluctuations may be divided into three main types, namely, long range, seasonal and short period fluctuations. Long range fluctuations vary from four feet on Lake Superior to six-and-a-half feet on Lake Ontario between the highest and lowest monthly mean levels of record. These fluctuations are due to periodic changes in the precipitation quantity and distribution, but the relationship is not a direct one, being complex and modified by several factors. A succession of years of excess precipitation is necessary to cause high lake stages. Several years of high precipitation are required to build up the ground water storage and to fill the numerous inland lakes and swamps of the drainage basin. Such storage also prevents a rapid fall of lake levels at the beginning of a period of deficient precipitation. A study of the past 95 years of record reveals that the long period change does not follow any particular recurring sequence.

Seasonal fluctuations are the only ones which follow a definite cycle. The highest lake level in a particular year is usually reached during the summer months, and the lowest level during the winter months. In each case the extreme values occur first on the lower lakes and progress to Lake Superior with the advancing seasons. The average seasonal range between the low monthly average and the high monthly average is 1.8 feet on Lake Ontario, 1.6 feet on Lake Erie, 1.1 feet on Lake Michigan-Huron and 1.2 feet on Lake Superior. Occasionally the lakes depart from the usual cycle of summer rise and winter fall.

While long range and seasonal fluctuations are caused for the most part by a change of the amount of water in a lake, short period fluctuations result from an unbalanced condition in the lake surface. This condition is caused by winds, differences in barometric pressures and lunar tides. Tides and the ordinary changes in barometric pressures are inconsequential, but changes due to winds and to steep gradients in barometric pressure may be quite large. When imposed upon lake stages which are generally high or low, they may cause excessive extremes in either direction.

Short period fluctuations experienced in the past on the Great Lakes have lasted from several minutes to several days and have ranged in magnitude up to about nine feet above the general level. Such marked changes occur at the ends of the long axes of lakes or

portions of lakes where winds blow over the greatest reach, causing high stages on the lee shore and low stages on the windward shore. Maximum stage differences occur in Lake Erie because its long axis lies on a southwest-northeast prevailing wind line, and its shallow depth offers little opportunity for the wind driven upper water to return through reverse currents beneath the depth disturbed by storms. Gages located at Buffalo and Toledo have simultaneously registered more than thirteen feet difference in elevation of the water surface at the ends of Lake Erie.

The steep gradients in barometric pressure previously mentioned, sometimes accompanied by squalls, infrequently cause sudden rises of the order of three or four feet. These are popularly called "tidal waves", and may approach a shore on a comparatively calm day with little warning. Considerable property damage has been reported in the press as a result of these occurrences. On May 5, 1952, such a disturbance occurred on southern Lake Huron. The gage at Harbor Beach, Michigan, at 5:30 A. M. showed a rise of about two feet and at 6:00 A. M. a fall of equal amount from the general level. At intervals of approximately one hour until 11:00 A. M. the disturbance was repeated with less range in stage. This particular fluctuation has the characteristics of a seiche, which term is often erroneously applied to any sudden rise of lake level. A true seiche is characterized by the oscillatory movement of the wave at regular intervals, and usually takes place in a relatively small or confined area, enabling the wave to reverberate from shore to shore. A similar disturbance occurred in Lake Michigan in June 1954.

The natural factors affecting long range fluctuations are precipitation, evaporation, flow in the connecting rivers and the movement of the earth's crust. So far it has not been possible to establish a definite relation between precipitation, evaporation and lake levels to enable the latter to be predicted with any assurance. Precipitation on the lake surface has a direct effect of raising the levels by the amount of precipitation, but that which falls on the drainage basin is subject to many influences, determining how much of the water ultimately reaches the lake. The time of year, type and condition of soil, extent and kind of vegetation and height of ground water all play a major part in determining the amount of run-off from a given area. Data and studies on evaporation from the Great Lakes are sparse and it has been estimated by various authorities to range from about one-and-a-half feet annually on Lake Superior to three feet annually on Lake Erie. Prospects for a satisfactory correlation of precipitation, evaporation and lake levels are not particularly bright. However, instrumentation and methods of analyzing have been improved, more basic data are available, and studies are proceeding.

Seasonal variations, like those of long period, are dependent upon precipitation and evaporation. After the effects of heavy spring and summer rainfall have passed, lake levels begin to recede. The recession is accelerated by freezing weather which reduces the amount of precipitation reaching the lake from the drainage basin. From the winter low the lakes rise to the summer maximum as a result of release of water from the spring break-up and increased precipitation.

The factors affecting river flow and therefore affecting lake levels are usually man-made, with one major exception. In the early years of the record when the rivers were in their natural state, the generally high lake levels were attributed in part to prolonged ice jamming in the rivers. In modern times due to improvements, controls and ice breaking, fluctuations caused by ice jams have been greatly reduced. However, for the St. Lawrence River it is estimated that during the winter months the flow is reduced by about six percent due to the effect of ice, and on the St. Clair and Detroit Rivers, the monthly average flow has been reduced in the past by as much as 90,000 cfs due to ice jams. The effect on Lakes Michigan and Huron of such a reduction would be a rise of approximately 0.2 feet.

The effect of crustal movement of the earth on lake levels has long since ceased to be theoretical, and has become a measurable quantity with practical application. The phenomenon is usually attributed to isostatic recovery of elevation following depression of the crust due to the weight of the glaciers. In general the coasts of all of Lake Ontario, all of Lake Erie, most of Lake Michigan, and the southerly shore of Lake Superior are subsiding in relation to the lake outlets, therefore along these coasts lake levels are rising with respect to the shore. The coasts of all of Lake Huron, the northeasterly part of Lake Michigan, and the northerly shore of Lake Superior are rising in relation to the outlets, therefore along these coasts lake levels are lowering with respect to the shore. The maximum rate of lowering is 0.7 foot per hundred years at French River on Lake Huron, and the maximum rate of rise in levels is 1.1 feet per hundred years at Port Dalhousie on Lake Ontario. Other typical rates of rise are 0.9 foot at Duluth and 0.6 foot at Chicago per hundred years. The study of the rates of crustal movement is being continued by the U. S. Lake Survey and in addition, the Canadian Technical Agencies are making extensive studies. The efforts of the two countries are being coordinated so that the final results will be in agreement.

Changes in levels of the lakes have been caused by works of man as well as by natural phenomena. These works consist of diversions of water principally for power and navigation into, out of, or within the lakes basin, locks and various control structures in the outflow rivers, and dredging improvements in river channels. Due to the large capacity of each of the lakes, few of these changes have any immediate appreciable effect. In many cases the full effect upon lake levels is not realized for about ten years. The net total effect of all diversions, control structures and improvements is in the order of only a few inches, which compared to the range in levels due to natural causes is extremely small.

No cycle of high and low lake levels from a long range viewpoint is evident. Many attempts have been made to establish one by various methods including correlation with the sun spot cycle, the growth of tree rings and even the highs and lows of the nations' business conditions. Likewise, attempts have been made to predict future elevations by statistical means. Some success has been achieved with this method for forecasts a few months in advance. It appears that the previously mentioned correlations of the natural factors of precipitation and evaporation with lake levels

offers the most fertile field for future study, therefore, this course is being actively pursued by the U. S. Lake Survey. Even though the natural range of fluctuation may some day be reduced through regulation of all the lakes, a reliable forecast of lake stages would render a highly important service to those who are vitally concerned with this subject.

The high lake levels of 1951 and 1952 and the resulting damage to shore properties created an unusual amount of interest and publicity. The high levels were the result of a period of above normal precipitation in the Great Lakes Basin. The damage resulting during this latest period of high water was greater than the damage of other comparable periods of high water, due mainly to the occurrence of severe storms and the unusually large amount of shore property development since the last previous period of high lake stages.

Lowering the high stages or reducing their frequency would alleviate the damage to shore property and the only feasible way by which this can be accomplished appears to be by lake regulation. In June 1952, the House Public Works Committee authorized a comprehensive detailed survey investigation of the Great Lakes which would best serve the interests of all water-users, namely, shore interests, navigation and power. This survey study is progressing steadily under the direction of the Division Engineer, North Central Division, Corps of Engineers.

Lake Superior has been under control by means of works at its outlet in the St. Marys River. The regulation of this lake is under the direct supervision of the International Lake Superior Board of Control appointed by the International Joint Commission. Under the Lake Levels Report, the Corps of Engineers is studying other methods of regulation of Lake Superior to determine whether the present method can be improved in the overall interest of all water users.

Studies are being made to determine the feasibility of regulating Lakes Michigan-Huron so as to reduce the extreme high stages which cause serious damage to shore property. It appears that the cost of channel enlargements and control works in the St. Clair and Detroit Rivers between Lake Huron and Lake Erie would be very large in order to give any substantial benefit to property owners.

Studies made to date of Lake Erie indicate that a plan to regulate this lake which will provide benefits to power and to shore property, and at the same time protect the interests of navigation, is feasible. Such a plan of regulation would reduce the natural fluctuation range of Lake Erie levels and would effect a significant reduction in extreme high stages. It would also increase the prime flow for power at Niagara River plants.

In connection with the St. Lawrence Seaway and Power projects, Canadian and United States agencies have conducted Lake Ontario regulation studies under the supervision of the International Joint Commission. A plan is being considered that will reduce the natural fluctuation range of six-and-a-half feet to a range of about four feet. This plan includes the reduction of extreme high stages with resulting benefit to shore property interests, the raising of lower levels with benefits to navigation and the increasing of prime flows in the St. Lawrence River with benefit to power.

The Great Lakes form a very complex hydraulic system. The problems pertaining to the hydraulics of the Great Lakes require considerable careful engineering study to assure that all interests are given appropriate consideration, and that the most beneficial comprehensive use is made of one of the most valuable natural resources on the North American continent.

BEACH EROSION[1]

by

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Michigan Water Resources Commission

To establish the need for research and to acquaint you with the seriousness of beach erosion along the shoreline of the Great Lakes, I should tell you that a Corps of Engineers Damage Survey completed in May 1952, revealed $62,000,000 in damage to this shoreline during May 1, 1951, to May 1, 1952, due to beach erosion and inundation. Michigan, with 3,121 miles of shoreline, suffered nearly $22,000,000 in damage, slightly over one-third of this total. The processes causing beach erosion are continuous, their activity depending upon the lake levels and storm activity on the lake surface. Hence, there is a real and pressing need for studies dealing with the causes and control measures of beach erosion on our Great Lakes.

The 1952 summer high level on Lakes Michigan-Huron of 582.77 feet, the highest on record since the mid-1880's, was the result of cool, wet summers of low evaporation rates and excessive rainfall in the Great Lakes Basin. Michigan received a surplus of 14 plus inches over the average during 1949-50-51. During the fall of 1951 and the spring and summer of 1952, the Michigan shoreline suffered savage attacks causing several millions of dollars in damage to property.

The Beach Erosion Board of the Corps of Engineers is probably the most active and best known agency in this country completing scientific investigations and studies of the many phases of beach erosion. Listed are six of their many published reports. These reports present particularly useful data dealing with Great Lakes erosion:

1. Wave and Lake Level Statistics for Lake Michigan, Lake Erie and Lake Ontario.
2. Study of Characteristics and Forces of Wind Generated Waves.
3. Laboratory Studies of Shock Pressures of Breaking Water.
4. Effect of Fetch Width on Wave Generation.
5. Generation of Wind Waves over a Shallow Bottom.
6. Sand Movement by Waves.

In addition to these research activities, the Beach Erosion Board, under federal statutes, may engage in the investigation of and plan control measures for local beach erosion problem areas on a cooperative basis with local units of government. Below are listed such studies completed or in process:

Wisconsin:	City of Kenosha frontage.
	Cities of Manitowac - Two Rivers frontage and Wisconsin State Trunkline.
	County of Milwaukee frontage.
	County of Racine frontage.
Michigan:	Portion of Berrien County frontage (in process).
Illinois:	Entire frontage of the state; study initialed as cooperative project, later completed by State.
Ohio:	Eleven completed studies.
New York:	New York State Park on Lake Ontario by Division of Parks, Department of Conservation.
Pennsylvania:	Presque Ile Peninsula on Lake Erie.

Also recommended to you for reference is the published "Proceedings of the Fourth Conference on Coastal Engineering" held in Chicago in October, 1953. This conference was sponsored by the Council on Wave Research and the Technological Institute of Northwestern University. The information and data presented on scientific studies pertaining to shore processes and beach erosion become a "handbook" to one involved in these problems.

Michigan's efforts have been designed to assist the individual at the scene of the problem. Initially, a cooperative research project was established between the Department of Conservation and the Lakes Hydraulics Laboratory of the University of Michigan. Later, the Water Resources Commission, after a change in state statutes, continued these cooperative efforts with Dr. E. F. Brater, who heads the Lakes Hydraulics Laboratory at the University of Michigan.

Three publications have resulted from this cooperative work between the state and university:

No. 1 "Bibliography on Beach Erosion and Related Subjects". Research publication No. 1 of Lakes Hydraulics Laboratory, Department of Civil Engineering, University of Michigan (700 references with 140 summaries).

No. 2 "Beach Erosion in Michigan" . Some history of shoreline development and beach erosion. Study of processes along Michigan shoreline. Wave tank studies of special problems.

[1]Mr. Granger's account was illustrated with numerous lantern slides of shoreline erosion and repair.

No. 3 "Low Cost Shore Protection for the Great Lakes". Presents valuable data on control works for shoreline protection.

These publications are made available to the public free of charge.

In the fall of 1952, staff of the Water Resources Commission combined with the Corps of Engineers personnel to prepare a shore processes study near Saugatuck, Zwemmer Beach north of Holland and at a third site north of the White Lake piers, all on Lake Michigan shoreline. Unfortunately, lack of funds first at federal level and then at state level have precluded additional needed field investigations at these sites.

Thousands of dollars have been spent and most of the experimentation has been accomplished by individuals and resort associations along the Michigan shoreline in constructing many types of beach erosion control structures. These works are of every type conceivable. Many were constructed on the advice of some individual who claimed to be "all wise" on the ways of the lake. Still other installations were based on sound advice from agencies or engineers acquainted with beach erosion processes on the Great Lakes. The Water Resources Commission began a "reconnaissance" program in September of 1951 of a number of such installations representative of the several different types of control measures built along the shore. Dr. E. F. Brater joined in this "reconnaissance" field study, and much of the data presented in Bulletin No. 3 was based on these field studies.

A seawall is not often a solution to the control of lake erosion, although a seawall of large limestone blocks deposited in a flat slope has been used successfully by the State Highway Department to protect U.S. Highway 2 west of St. Ignace at a cost of several hundred thousand dollars.

Groins built out at right angles to the shoreline are generally effective in capturing and holding sand deposits and protecting the shoreline from erosion. Successful groins have been constructed from sheet piling of steel or timber. Log cribs filled with stone have also been used very successfully.

Timber groins cost from $20.00 to $25.00 per lineal foot, reinforced concrete and interlocking steel sheet piling runs from $40.00 to $100.00 per foot, so installations usually cost from $2,000.00 up.

GEOLOGY

by
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Geology Department,
University of Michigan

*

My comments are going to be brief, because actually there is very little we know about the geology of the Lakes if we restrict ourselves to the areas that are actually within the basins of the Great Lakes.

Using the map which is posted here, let me refresh your minds a bit about the geological setting of the Lakes. I can then say a little about what you would like to know of the geology underneath the Lakes, what little bit has been done, and what some of the chances of doing more may be.

In the Lower Peninsula of Michigan, in southern Ontario, in the Upper Peninsula of Michigan (east of about Marquette) and down in eastern Wisconsin, we find sedimentary rocks of Paleozoic age as the bedrock. Farther north in Ontario and to the west of Marquette and all across the area north of Lake Superior and north of Georgian Bay, we find that the bedrock is Precambrian, part of the Canadian Precambrian Shield. Over most of the Great Lakes area, the bedrock is obscured by a cover of glacial drift which is as thick as twelve or fifteen hundred feet in the central part of the Lower Peninsula of Michigan, and exists over most of the Upper Peninsula of Michigan with at least thicknesses of ten to a few hundred feet—although in many places the bedrock crops out.

The basins of the Lakes are obviously controlled in large measure by the underlying geology, although the precise control is still a subject of considerable argument. The usual idea is that at least for the three large northern lakes, the lake basins were originally valleys of a stream system and that these valleys were modified by the glacial ice in its three to five advances over this area in the Pleistocene, each advance scooping out the basins to somewhat greater depth and leaving deposits piled up around their margins. After the first advance of the ice and the establishment to a certain extent at least of the present basins, the basins then guided the next advance and this became a sort of accelerating process, so that the basin existing from, say, the second glaciation guided the third one and the result was even more effective in shaping the basin, and finally with the advance and retreat of the last stage of the glaciation, the basins came into more or less their present shape.

Very possibly, some or all of the Great Lakes basins are (all or in part) structural basins of some sort, not inherited stream valleys carved out by the glacial ice. More and more support has grown for this idea for Lake Superior, and possibly for Lake Ontario, although as well as being a structural basin it may well have been a valley or a stream at the same time.

Attention has been called to the fact that many times the basins of Lake Huron and Lake Michigan lie approximately where we might expect to get basins due to the leaching out of the salt deposits underneath (which we now find occurring under much of the Lower Peninsula of Michigan)—leaching out, with the collapse of the material above. The basins of Lake Michigan and Lake Huron lie within the escarpment that makes Bruce Peninsula and Manitoulin Island and the Door Peninsula, and this is where we might expect the leaching of the salt. How much this may or may not have contributed to the development of these basins is quite uncertain.

There were three things that we would like to know about the geology within the lake basins. First, we would like to know what is the bedrock geology underneath, whatever the fill of glacial and lake sediment there may be. This is a particularly important problem, not only for understanding the origin of the lake basins, but in order to match up the geology on opposite shores. Actually, although the width of Lake Michigan is not very great, the basin comes right at a point of considerable transition in the bedrock geology between the Wisconsin shore and the Michigan shore, even though we know it fairly completely on the two shores and only have a relatively short gap between. It is a rather critical region. The same is true for the Precambrian rocks in the Lake Superior region. The Lake Superior basin is considerably wider, which poses more of a problem, but it is also at a rather critical area where it is difficult to make a satisfactory guess across from one side of the Lake to the other. We are in not quite as bad a condition with Lake Erie and with Lake Huron, but particularly for Lake Michigan and Lake Superior, a knowledge of the underlying bedrock below the lake sediment and glacial sediment would be extremely helpful in working out the regional geology of this area.

Secondly, we would like to know something about the glacial sediments that are known to occur under the lake water in all of these Lakes. We have some little knowledge of them, which I will tell you about in a moment, but not very much. We know, for example, that some of the glacial moraines of Wisconsin cross through the lake basin as low or buried ridges in Lake Michigan, and can be picked up again on the Michigan shore. If we knew considerably more about this material and the distribution and glacial sediments in the lake basins, we could at least gather more satisfactorily the glacial history of the Great Lakes.

Thirdly, there is the sediment that has been deposited in the Lakes since the last glaciation ten to fifteen thousand years ago. We have some vague ideas

of its nature in a number of places and we have some idea of its thickness in some areas, but on the whole we know relatively little about it.

There are two ways to go about learning something about the geology where it is covered by the water of a lake or the water of an ocean. We can do it by a direct method of going down and looking at it, if it isn't too deep. Some of this has been done in shallow areas, particularly in Lake Huron and in Lake Erie. But I am going to exclude that information from my comments here, because I think we should be a little more concerned at the moment with the material that is so deep that we are going to have to get at it by some more indirect method, material that is pretty well excluded from our having an actual look at it in place. We can bring up samples of it, either just some material from the bottom, or in some cases we can bring up a core as long as forty or fifty feet under very favourable circumstances. This is about the limit that we can hope to get up samples out of the bottom, and this, of course, in many cases will not get us to bedrock. This brings us to completely indirect methods of examining the lake bottom by some sort of geophysical means. A number of these methods have been used in the oceans. Very few of them have, as yet, had any use in the Lakes. It is possible to do some seismic prospecting, firing off explosions in the water and measuring the velocity of the waves in the rock on the bottom, and from this determining something about the rock. A little experimental work of this sort has been done in the Green Bay area. Except for that, I know of no work of this kind yet in the Lakes, although I think some will be done within the next few years. By making measurements of the earth's magnetic field or the earth's field of gravity, it is also possible to deduce something about the underlying rock, and this is going to be our best hope to learn something about the bedrock under the lake basins.

As for the lake sediment itself and the glacial sediment, there is a great deal yet to be done by taking cores out of the lake bottoms. At least two sets of cores have been taken in the Great Lakes, and there may be others that I do not know about. Several summers ago, Jack Hough of the University of Illinois took some cores out in the Lake Michigan basin. I think his longest core was about twenty feet. It was deep enough so that it got into lake sediments that were apparently deposited at a time when the lake level was a great deal lower than it is now when Lake Michigan consisted of two relatively small lakes, one in the southern part of the present lake and another relatively small lake in the northern part. He came to this conclusion from the nature of the sediment, and this conclusion fits in quite well with information from geology on the shore and from some other later information. He found actual glacial sediment in a number of places, but was not able to get satisfactory cores of it. It is relatively hard and usually it is difficult to get a corebarrel more than a few inches into it, but at least he was able to identify glacial sediment under the lake sediment in several localities.

The summer before last, Professor Zumberge of the Geology Department here took some cores in Lake Superior, working off the U. S. Fish and Wildlife vessel, the "Cisco". His longest core was, I believe, about nine feet, and was not sufficiently long for him to draw very many conclusions about the post-glacial history of Lake Superior, although he found at least two distinct types of sediment. Also in Lake Superior, he found glacial sediment under a cover of only a few feet of lake sediment, and so we have at least enough work done to know that here is a very fruitful approach.

From the fathometer records that have been taken, it is evident that there is considerable topography in the glacial deposits on the lake floor and that a lot of this topography is subdued in lake sediments that have been deposited since the glaciation. This evidence comes where, in taking a fathometer record, one gets what looks like a double bottom. There is an echo-sounder reflection from the mud on the bottom and a second reflection from below a cover of the soft lake mud. There is evidence that considerable topography in the glacial sediments is filled in by the lake deposits.

In the shallowest of the lakes, Lake Erie, we have somewhat more information. The State of Ohio has been doing quite a lot of work, most of which I am not familiar with, and some of which has not been published yet—data particularly concerned with the areas of sand in the lake.

The first major project that the Great Lakes Research Institute did was in the island region of western Lake Erie. Cores were taken through the sediment in the lake bottom down to the limestone. I think the most important contribution to this study was the discovery that there is considerable relief to the limestone surface. There is a Karst topography completely or partially buried in the lake sediments. This lake, of course, affords much easier working conditions for projects of this sort, because in the forty-five feet of water in the western end, it is possible to anchor a raft and proceed with what amounts to almost land-type drilling equipment; whereas, in the deeper basins in five hundred to one thousand feet of water, we have not any chance to do anything of that sort, and one must use deep water methods.

This gives a little outline of the things that we would like to know, some of the starts that have been made, and some of the starts that we hope to make ourselves or hope somebody else will do in the relatively near future. I will leave our summary of geological information at this point.

CURRENTS AND WATER MASSES OF LAKE HURON

by

John C. Ayers
Department of Conservation, Cornell University

Because of their great sizes and depths the Great Lakes require the application of oceanographic methods and equipment. This fact explains in part why I, an oceanographer, am participating in this discussion.

In the summer of 1954 the Great Lakes Research Institute of the University of Michigan initiated the first phase of what is conceived to be a long term investigation of the Great Lakes. Although the aims of the Institute are broad, the initial studies were directed toward obtaining specific information on the currents and circulation of Lake Huron. A similar study of Lake Michigan is being carried out this summer.

Knowledge of the currents, water masses and vertical circulation is essential for the planning of future basic investigations. Such knowledge will be required also in the solution of many practical problems concerned with water quality, waste disposal, beach erosion, and biological productivity.

The Lake Huron study was planned to provide essentially simultaneous observations at a large number of positions throughout the lake on June 28, July 27, and August 25. Such observations make it possible to construct for each of these days a picture of conditions existing throughout the entire lake. This is the so-called "Synoptic Survey Method".

Eleven vessels took part in the synoptic surveys of Lake Huron; six were provided by the Province of Ontario and five were furnished by the Great Lakes Institute and the U. S. Fish & Wildlife Service. Except in the upper and lower ends of the lake, these vessels steered V-shaped courses which met point-to-point so as to provide from each two vessels an X-like pair of crossings of the lake. At several predetermined areas along its course each vessel stopped to obtain observations of water temperature and other physical and chemical parameters.

The following account will not include the complete results of the 1954 synoptic surveys of Lake Huron but it will serve to illustrate, in a general way, the nature of the study and some of its achievements. It should also indicate some of the kinds of information we expect to obtain from the Lake Michigan surveys now under way.

In late June the surface current pattern was dominated by a large counter-clockwise eddy in mid-lake east of Alpena. A smaller counterclockwise eddy lay just off the mouth of Saginaw Bay and an elongate clockwise eddy paralleled the Ontario shore from Cape Hurd to Point Clark. Lake Superior water entering through Mississagi Strait, False Detour Channel and Detour Channel passed westward into the region east of Bois Blanc Island where it joined the inflow from Lake Michigan. Strong currents up to 0. 5 mile per hour carried the mixed waters southeastward to mid-lake east of Sturgeon Point where the flow appeared to divide. A small portion of the flow entered the major mid-lake eddy and the eddy along the Saugeen Peninsula. The major part of the current turned toward the Michigan shore and passed inshore of the eddy of Saginaw Bay. This water then passed to mid-lake east of Pte. aux Barques, returned to the Michigan shore at Harbor Beach, and continued down the shore until deflected across the lake by a small eddy off Lakeport. The water entering the St. Clair River came from the center and east half of the lower lake and flowed southwest to reach the river.

The distributions of temperature and the chemical parameters indicated that in late June the major portion of the lake was in essentially its spring condition of rather uniform nature and with no thermocline developed. Bottom water of Lake Michigan characteristics was present in the upper end of the lake and in the western half of the lake from Presque Isle south to the level of Bayfield, Ontario. From Manitoulin Island southward the eastern side of the lake contained bottom water intermediate in characteristics between Lake Michigan and Lake Superior waters. This is the Lake Huron water.

Upwelling of bottom water occurred in the large mid-lake eddy, in the eddy off Saginaw Bay and offshore west of Goderich. Minor upwellings were present east of Point St. Ignace, along the south shore of Manitoulin Island, off Sturgeon Point, and between Pte. aux Barques and Harbor Beach. Major sinkings of surface water were observed along the concave shore of the Saugeen Peninsula, near Point Clark, and along shore near Bayfield, Ontario. Smaller areas of sinking were present on the south shores of Drummond and Cockburn Islands and in Hammond Bay.

From plots of the distribution of the water's specific volume anomaly (a method too complicated to describe here) a pattern of probable bottom water movement was obtained. Strictly, this is the pattern at the sixty-meter level, though it probably applies to greater depths as well. While highly subjective this pattern appears to be completely reasonable; where the method requires direction arrows to come from shore there are completely independent evidences that sinking is taking place along shore and where the method requires direction arrows to approach shore there are independent data indicating upwelling.

Water from the sinkings along Drummond and Cockburn Islands and in Hammond Bay joined other bottom water and flowed very slowly eastward toward the opening of Georgian Bay. In that region a part was contributed to the upwelling along Manitoulin Island while the greater part passed southwest, receiving water from the sinkings along the Saugeen Peninsula and at Point Clark, to rise to the surface in the upwellings off Sturgeon Point, off Saginaw Bay, and off the tip of the "Thumb". Bottom water formed in sinking near Bayfield appeared to pass northwestward to the upwellings off Goderich and off the tip of the "Thumb".

This briefly summarizes some of the results of the June survey. The June survey took place under essentially normal winds (southwest to west by north). The July survey followed winds which were from quarters much more northerly than normal, winds prior to this survey were from west by north to north by east. The effect of the change in wind direction was a distortion of the circulation pattern observed in June.

Between the June and July surveys a strong thermocline developed over the entire lake at about fifty feet below the surface. The warm light waters above the thermocline were undoubtedly more responsive to the shifts in wind direction than were the colder more dense surface waters of earlier in the year.

The surface currents on July 27 were characterized by weak currents along nearly all of the Canadian shore. The large mid-lake eddy had been replaced by weak west to east currents and the eddy off Saginaw Bay had been pressed close against shore near Oscoda. Mixtures of Lake Michigan and Lake Superior waters moved southeastward in all the upper end of the lake, with the most rapid currents close against the Lower Michigan shore. From Presque Isle to Oscoda the currents ran nearly south at about 0.75 mile per hour. Most of this flow appeared to pass inshore of the eddy off Oscoda, to enter the north side of the mouth of Saginaw Bay and to cross the bay, emerging around the tip of the "Thumb" and staying close to the Michigan shore to about Richmondville. From here it crossed the lake southeastward to the Ontario shore and flowed southwest to the St. Clair River.

The formation of the strong thermocline had cut off the bottom waters from the mixing action of the wind; being now subject to mixing by only molecular diffusion and by the firctional effects of the weak bottom currents, the bottom waters of the lake were much less uniform than in June. Small masses of Lake Michigan and Lake Huron waters lay side by side and apparently followed closely one after another, for in areas where their upper edges reached into the thermocline, the upwellings brought to the surface waters with the chemical characteristics of these two bottom water masses but without the concomitant temperature characteristics of bottom water.

The weaker surface currents and the strong thermocline in July reduced the number of clearly defined areas of sinking and upwelling. The major region of sinking was in the concave shoreline of the Saugeen Peninsula where cross-lake current impinged on the shore. Major upwellings were present near Presque Isle where surface currents moved away from shore and off Oscoda where a divergence of surface currents occurred. Small and less well defined upwellings and sinkings were deduced in a few other places.

In July the movement of the bottom water appeared to be more predominantly along the axis of the lake than in June. Major contribution of bottom water appeared to be from the sinking along the shore of the Saugeen Peninsula, with lesser contributions from small sinkings near Manitoulin Island and near Sturgeon Point. Well defined upwellings were indicated near Presque Isle and off Oscoda with minor ones in the lower end of the lake and near the east end of Manitoulin Island. As was the case in June, the regions of sinking and upwelling indicated by the direction of the bottom water agreed very well with those suggested by the surface currents and the chemical parameters. The calculated velocity of the bottom water movement was of the order of a millimeter per hour, slightly less than had been computed for its velocity in June.

In July, bottom waters of Lake Michigan characteristics could be followed, with progressive dilution, to the offing of Lexington, Michigan. Lake Huron water again dominated in the bottom of the eastern half of the lake and increased in abundance toward the lower end of the lake.

Prior to the survey of August 25 the winds had returned to more nearly normal westerly quarters (west by south to northwest by north) and the surface currents had a pattern more nearly like that of June. The large mid-lake eddy was partially re-established and the lesser eddies of the lake were in essentially, though not exactly, the positions they had occupied in June. The continued presence of a strong thermocline and the upwellings' continued 'sampling' of the thermoclinal portions of the bottom water produced a patchiness in the distribution of surface chemical parameters similar to that observed in July.

In August Lake Superior water from Mississagi Strait, False Detour Channel, and Detour Channel moved westward to join the inflow from Lake Michigan near Bois Blanc Island and the mixture passed southeastward along the shore of Lower Michigan; moving south and east off Alpena the current divided, with a part crossing the lake and going north in a counterclockwise motion while the major portion passed along the Michigan shore and inshore of an eddy off Saginaw Bay. The latter current entrained the outflow of Saginaw Bay, swung out to mid-lake east of Pte. aux Barques, and moved down the center of the lower lake to the vicinity of Kettle Point where it turned southwestward toward the St. Clair River.

As in July, the bottom waters of the lake were composed of small and roughly alternate masses of Lake Michigan and Lake Huron water. Lake Michigan water could be identified as far south as Harbor Beach; Lake Huron water again dominated the eastern half of the lake basin and increased in amount as the Lake Michigan water decreased.

In August major sinkings were located along virtually all the Ontario shore with lesser ones along the south shore of Manitoulin Island and in the Hammond Bay region. Major upwellings were situated along the Michigan shore from Presque Isle to the mouth of Saginaw Bay, with smaller ones in an eddy northeast of Rogers City and on the east side of Point St. Ignace. Minor sinkings and upwellings were indicated in other parts of the lake.

The movement of the bottom waters in August appeared to be primarily along the long axis of the lake. The velocity of these movements was calculated to be somewhat greater than in July or June. Significant contributions of bottom water were being made by the sinkings along the Ontario shore and significant losses of bottom water appeared to be taking place in the upwellings along the Lower Michigan shore. The lesser sinkings and upwellings indicated by the directions of the bottom water were, as before, well substantiated by the surface currents' relations to land

and to each other and by the distributions of the chemical parameters.

In a presentation of this nature it is impossible to present all the data or to discuss all the evidence leading to the conclusions drawn. I do, however, wish to leave the impression that a logical and coherent background of knowledge about the circulation of the lake has been obtained. Knowledge of this basic character is prerequisite to a sound approach to nearly every chemical, biological, or physical phenomenon of the lake. Aside from this fundamental consideration there is the very real possibility that completion of the St. Lawrence Seaway may raise important practical problems for the solution of which this sort of knowledge is required.

FISHERIES OF THE GREAT LAKES

by
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Chief Great Lakes Fishery Investigations
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It is especially fitting that a discussion on fisheries should conclude these sessions on the current status of basic research in the Great Lakes.

Fisheries might include, in the research problems which bear on them, everything that has been said during these panel discussions. Fishes culminate the pyramid of aquatic productivity and represent the major crop of interest to man. Thousands of people in the United States and Canada depend entirely upon that crop, i. e., upon the fishes which they can harvest, for a livelihood. As of recent years, the Great Lakes have produced in an average year about 105 million pounds of fishery products, approximately 78 million pounds from United States waters and 27 million pounds from Canadian waters.

Research of a sporadic nature has been done on the Great Lakes fisheries for many years. Occasional studies of isolated segments of the fishery were made as early as 1874. The research effort has increased gradually since then with occasional surges in tempo as money for specific purposes was made available. Several of the states essentially interested in lake fisheries recognized early that to do anything with the fisheries on a systematic basis, the Great Lakes must be considered as large ecological units, not necessarily bounded by political subdivisions. Therefore, there was early demand for work to be done by an agency that was not limited by State or for that matter international boundaries. The Fish and Wildlife Service and its predecessor, the Bureau of Fisheries, undertook a continuous program some thirty years ago. The investigations carried on at that time were limited and depended almost entirely upon the catches of the commercial fishermen for their basic data. A remarkable accumulation of facts regarding Great Lakes fisheries came out of that work.

About 1947, fishery investigations were increased rapidly. The establishment of a population of parasitic sea lampreys in the Great Lakes above Niagara Falls and its subsequent depredations had seriously affected the pocketbooks of a great many people. Along with the Fish and Wildlife Service the Great Lakes states and the Province of Ontario undertook research programs to find means of relieving this distressing situation. Research efforts were generally divided into two major categories; a search for means of controlling the sea lamprey; and an attempt to measure the status of and changes in productivity of the lakes generally. The sea lamprey had ruined the lake trout in Lake Huron and seriously threatened to do the same in Lakes Michigan and Superior. As of 1952, Lake Michigan trout production was also ruined.

That meant a loss of approximately 10-1/2 million pounds of lake trout production per year from Lakes Michigan and Huron. Since the lake trout is a high-priced fish, the loss represented approximately five million dollars annually to Canadian and United States fishermen.

In 1949 the U. S. Congress appropriated to the Department of the Interior, Fish and Wildlife Service, a rather large sum of money for research. The Congress has continued its support of this work to the present.

The research started with an investigation of the sea lamprey's life history in order to pick out weak points at which control could be aimed. At the present time, we have developed two systems of control which appear to be at least feasible:

(1) The stopping of the essential upstream migrations of sea lampreys when they emerge from the lakes to spawn. Fortunately, sea lampreys die shortly after reaching sexual maturity whether they spawn or not.

(2) A poisoning technique which can be applied to the five generations of larval lampreys which live harmlessly in our streams. These larvae metamorphose into parasitic adults, a generation each year, and go to the lakes to return to the streams a year later to lay their eggs. This poisoning has taken two directions. One method has been tried experimentally by Canada. The other method has not been tried as yet and is still under investigation. Mass poisoning with no regard for accessory fishes works very well. Preliminary experimentation by Canada has shown that 85 percent of the larvae in the streams can be eradicated. Naturally, some of the fishes are killed.

In the United States, we have pursued a very elusive thing known as a "selective toxicant". We have gone over approximately 4500 chemicals to date, and have at the present time about eight which show some specificity for lamprey larvae. These must be tested further and exhaustively, so that when applied to the streams of the states the risk of killing or damaging in any way our very important stream sport fishes will be minimized.

Some of the things we know about sea lamprey control have been applied to streams of Lake Superior with the idea of saving that single remnant of lake trout stock.

The Fish and Wildlife Service built a 60-foot research vessel, Cisco, in 1951. She is equipped not only to fish but also to obtain hydrographic and limnological data. This vessel has made possible a general, exploratory limnological study of the three upper Great Lakes, a full season of work on the life history of lake trout in Lake Superior, and almost two seasons of work on conditions in Lake Michigan.

In studies of Lake Michigan, the Cisco has turned up large masses of information which indicate that the lake trout is a thing of the past. Presumably, the same thing can be said of lake trout in Lake Huron. By checking the catches of commercial fishermen out for other fish, we have determined that the stock of

lake trout has been reduced more than four hundred times below the abundance level that existed in 1931 and 1932. There is strong evidence that this condition is worsening rather than improving. Sea lampreys in those lakes are now living on chubs (Coregonidae), the only exploitable fishes remaining in deep water.

This sad condition of lake trout stocks points up another project which we have undertaken in Lake Superior (and which the lampreys might spoil before we have results). We must learn how to obtain the best results from artificially propagated lake trout if we undertake to rehabilitate the stocks in Lakes Michigan and Huron. We don't know very much about the culture of lake trout beyond the point where they leave the hatcheries. We are not too well informed as to where, when, how, and at what sizes we should plant lake trout. The Great Lakes states, Canada, and the Fish and Wildlife Service have been marking hatchery-reared lake trout for planting in Lake Superior during the past three years. These fish are planted according to plan to determine whether it is wise to plant in the spring or in the fall, to determine the best depth of water in which to release the fish, and what size at planting will give the best survival. We are getting some evidence. It would seem that fish planted in the spring after having been held in the hatchery for a year do survive in markedly greater numbers than fish stocked in the fall, even though they are about the same size—why, we do not know.

We see a fairly optimistic future for fishery and related researches in the Great Lakes. During the past five years there have been several accomplishments in the administrative field which should provide for better research and more continuous effort. One is a treaty between the United States and Canada covering fishery research and sea lamprey control in the Great Lakes. This treaty does not grant any regulatory power over the harvest of fish, but it will enable us to put our efforts together. With this treaty, we can coordinate the research of all interested groups and bring enough strength and effort together to solve many important problems hitherto recognized but difficult to attack because of the need for simultaneous observations at many points.

Canada has made excellent progress in the development of her Great Lakes research facilities. In the past three years, they have established a Federal-Provincial Committee on Research, and they are implementing a sound investigational program on all five lakes. I cannot take the time to describe their program in detail. It is essentially like ours. They are very much interested in the sea lamprey and in the major species on which the sea lamprey is preying. They are also interested in hydrography, as well as in the physical, chemical and biological conditions that make for good fishing and sustained production.

I trust this brief outline will enable you to grasp the extent and status of fishery research on the Great Lakes. I hope I have left you with the distinct impression that all of our diverse fields of endeavor—engineering, navigation, meteorology, geology, etc.—are closely related and have a very definite bearing on the extent of knowledge and especially understanding in the field of biological productivity.

Q. I would like to ask Col. Gallagher: has the rate of decrease in lake levels since the high of 1952 been what was expected?

A. It has been decreasing. Last fall, we had an unusually heavy precipitation in October and the lakes appeared to be starting up again. However, after that large inflow, the upper lakes settled down and Michigan-Huron has been rising very slowly since then, and Superior has been on a downgrade. Ontario and Erie looked for a while as if they would approach their '52 high. However, they have reached lower maximums this year than in 1952. We expected that by this time the lakes would probably be slightly lower than they actually are, and it appeared up until last summer that the maximums were decreasing in a downward cycle which occurs from time to time, and the large inflow appeared to throw that cycle slightly off. As far as forecasting is concerned, we only forecast the summer high based on the winter low, but the general trend of the lakes is an upward and downward movement and once a high is reached, as in '52, generally, we can expect several years on a downward trend.

Q. We have had a sort of plateau over the past few years, more so than usual after a peak rise, haven't we?

A. No. In the 1870's and 1880's, we had conditions somewhat similar. Lake Ontario, which I have been working with more often recently, reached highs in 1862, 1870, 1876, 1886—and then from about that point until 1926, it went on as you might say in a plateau. Then about 1926, it reached an all-time low and then immediately jumped up to what was then an all-time high in 1929. Then in the '30s we had a long dry period. The lowest supplies on record were in the '30s. In the '40s there was a gradual rise which reached its peak in '52, and it would appear that there is now starting a gradual downward trend. There are no definite cycles. That may continue for three, four, five or even for ten years on sort of a plateau, or on a downgrade.

Q. Are these conditions directly correlated with the precipitation?

A. No. We have attempted to correlate lake levels and precipitation, but there are so many things involved in addition. A good example is March of this year when in Lake Ontario we had the greatest supply in history for that month. I think precipitation was higher than usual, but not to that extreme and the reason for the high supply during that month was due to a number of factors. The ground was frozen and there was low evaporation, so that the water which fell on the land ran into the lake. It was cold and there were not too many sunshiny days. Now, maybe during the month of May the same precipitation would not give you anywhere near the same supply, because then the run-off would be retarded and evaporation would be greater. Over a year, the amount of water that falls directly on the lake surface for most of these lakes is about equal to the amount of water that evaporates, so that evaporation has a great effect. Something that we know very little about is whether there is any underground flow. There have been studies made of that sort, and it is still a questionable item.

Q. Col. Gallagher, is your office going to make an estimate of what difference the level of Lakes Michigan-Huron would be if there was unlimited discharge at Chicago?

A. It can be calculated—if I knew what you meant by "unlimited discharge"! The fact of a diversion can be calculated. You take the value of a diversion and divide it by what we call the increment of flow—in other words, it is a change in the outflow of a lake based on the change of one foot, and from that you can calculate the effect of any diversion. According to the present studies that we have made on the rate of outflow from Lakes Michigan-Huron to the St. Clair and Detroit Rivers, it appears that one foot of change in those lakes will cause a change in outflow somewhere between 13,000 and 14,000 cu. ft. per second, so if you want to find out what the effect of 1,000 is when it reaches its full effect, then it is 1,000 divided by about 13,500. That is when it reaches its full effect and it must continue from approximately ten to fifteen years steadily for you to get the full effect. The effect of a diversion on Lakes Michigan-Huron only has 25% of its effect at the end of the first year. The second year it is somewhere around 50% and third year it is about 65%. We figure 99% is about the maximum and that would be in about 15 years. The present diversion at Chicago is 3100 and has not been in effect long enough to have reached its maximum effect, so that the effect of it would be 3100 divided by about 13,500.

Adams. Colonel Gallagher, people are concerned about construction along the shoreline and also this matter of inundation which takes place along Lake Erie. We are anxious to know when this report is going to be forthcoming, by which they hope to have Congress act to reduce their extreme injuries. Do you have any date forecast for the completion of this report?

A. It will be sometime around the first part of 1957, I'm not positive.

Adams. I have a question for Dr. Moffett. During the intermission, we were talking about the disappearance of the walleyes in Saginaw Bay. I remember when we were doing a lot of work in Saginaw Bay in 1935, the walleyes used to come in there about Eastertime and then they would disappear. The commercial fishermen would be in there with their nets and they lost a lot, but the history of Saginaw Bay from a standpoint of pollution control makes me almost conclude that if walleyes have disappeared it's because pollution has also disappeared. All the sewage in the area is now treated.

Moffett. All we know is that walleyes have disappeared. We don't know why they went.

Van Oosten. If the phenol pollution has disappeared, why did the fish still have a phenol taste up to four years ago?

Adams. Phenol has been reduced from 1500 lbs. to 50 lbs. or less now. Walleyes were in their flower at the time when phenol and salt pollution was at a maximum.

Hile. Who was putting in the phenol and salt in the 1890s? There were lots of walleyes then!

Lagler. Yesterday and today we have heard quite a bit about the social and economic aspects of the Seaway Development, and we heard some of the problems relating to lake levels, wharfage, and so on. I wonder if any of the biologists in our aggregation today could tell me if there are any measurements that we ought to be making now with an eye to the future and the changes that heavy ship traffic is going to bring. Can we make any guesses as to some of the effects of increased traffic on matters of biological productivity, meaning the fish crops. Dr. Speirs, what is the thinking in Canada along this line? Has anybody been estimating this situation?

Speirs. If they are, I haven't heard about it.

Lagler. Well, maybe there are no serious things, yet certainly I can envision some changes in turbidity—at least locally, with heavy ship traffic.

Anderson. To supplement Dr. Speirs' observation, I might say that investigations are being made in the eastern end of Lake Ontario and the St. Lawrence.

Lagler. Dr. Moffett, you must have thought about this thing in connection with the work of the Fish and Wildlife Service on the lakes.

Moffett. We have thought of a wholesale decontamination service to stop sea lampreys hitchhiking on vessels should we ever get the local populations under control.

Ayers. We are going to have a good look at what is here before the seaway opens.

Lagler. Is there any thought given to the dumping of cinders by lake boats to avoid the spawning beds of fish?

Granger. No.

Closing remarks by Dr. Wilson

Before we close, I would like to thank all the people who have taken part in the presentations and discussions, and the speakers yesterday. I would also like to express our thanks to one very active member of this Institute who has not spoken, Prof. Sparrow, who did almost all of the arranging for these meetings.

I hope all of you have benefitted as much from these discussions as we have.

Meeting adjourned at 4:35 p.m.